Electronic Services - Los Angeles
M12972X

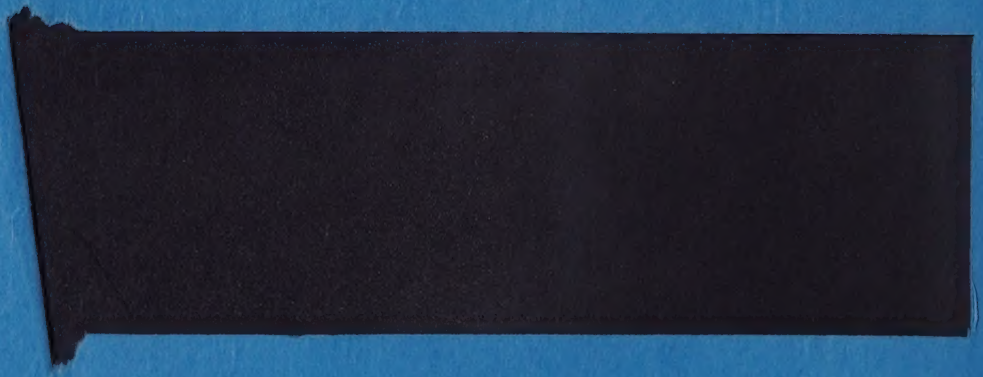
LOS ANGELES INSTRUMENTATION AND
COMMUNICATION EQUIPMENT SERVICE
223 WEST FLORENCE AVE.
INGLEWOOD, CA 90301

HICKOK

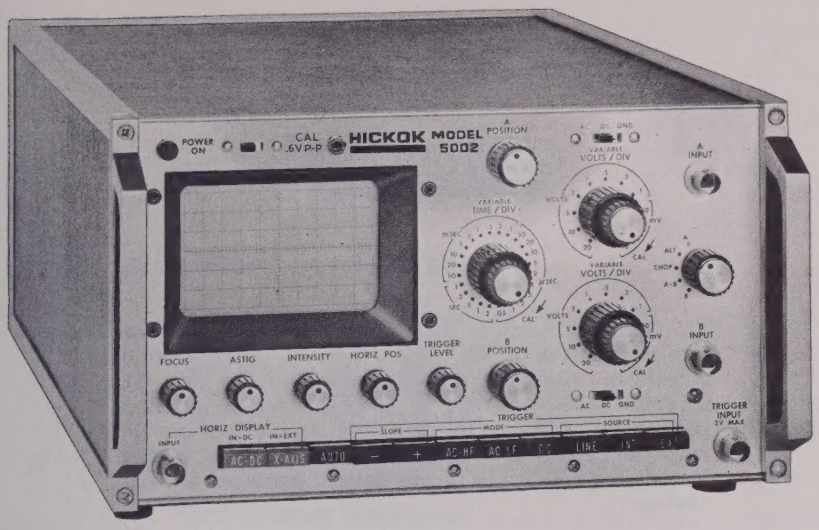
Model 5002

25 MHz TRANSISTORIZED OSCILLOSCOPE

HICKOK ELECTRICAL INSTRUMENT COMPANY
10514 Dupont Avenue • Cleveland, Ohio 44108 • Phone 216-541-8060



LOS ANGELES INSTRUMENTATION AND
COMMUNICATION EQUIPMENT SERVICE
228 WEST FLORENCE AVE.
INGLEWOOD, CA 90301



Model 5002

25 MHz TRANSISTORIZED OSCILLOSCOPE

© THE HICKOK ELECTRICAL INSTRUMENT CO. 1970

10514 DUPONT AVENUE • CLEVELAND, OHIO 44108

PHONE—(216) 541-8060 TWX—810-421-8286

PRINTED IN U.S.A.

2490-630

HICKOK

WARRANTY

The Hickok Electrical Instrument Company warrants this instrument of its manufacture to be free from defects in material and workmanship for one year (12 months) from the date of original purchase. Any instrument found to be defective during this period may be returned, transportation prepaid, to the factory for repair, or at our option, replaced without charge.

This warranty does not apply to any of our products which have been repaired or altered by unauthorized persons, or which have been subject to misuse, negligence, or accident, or which have had the serial number altered, effaced or removed. Neither shall the warranty apply where a warranty registration card has not been properly completed and returned to us promptly after purchase. This warranty is in lieu of all other warranties whether expressed or implied.

RETURNING EQUIPMENT FOR REPAIR

Before returning any equipment for service, the factory must first be contacted, giving the nature of the trouble. Instructions will then be given for either correcting the trouble or returning the equipment. Upon authorization, this equipment should be forwarded directly either to the Hickok factory address at 10514 Dupont Avenue, Cleveland, Ohio, 44108, or to a designated service station in your locality.

19120-158

TABLE OF CONTENTS

Section		Page
	General Information	1
I	Specifications	1
II	Operation	5
	General	5
	Vertical Controls	5
	Horizontal System	6
	Operational Checks	6
	Use of Probes	8
III	Applications	8
	Typical Voltage Measurements, Single Input	8
	Two Inputs, Separately Viewed	9
	Difference of Two Inputs	9
	Two Time-Related Inputs	9
	Typical Time Measurements	9
IV	Theory of Operation and Circuit Description	11
	Block Diagram Description	11
	Power Supply	11
	Vertical Amplifier System	13
	Horizontal Amplifier	15
	Time Base	15
V	Service Procedure	17
	General	17
	To Remove Cover Panels	17
	Recalibration	17
	Visual Inspection	17
	To Replace Cathode Ray Tube	19
	Troubleshooting	19
	Trigger Circuitry	19
	Sweep Generator	20
	Blanking Circuit	21
	Horizontal Amplifier	21
	Vertical Amplifier	22
	Delay Line	23
	Power Supplies	23
	Horizontal Board Wave Forms	24
	Vertical Test Points	24
	Delay Wave Form	25
	Power Supply Test Points	25
VI	Calibration Procedure	35
	Suggested Equipment for Calibration	35
	Calibration of Power Supplies	35
	Raster Shape Adjustments	35
	Adjustment of Calibrator Output	35
	Horizontal Amplifier Calibration	35
	Calibration of Horizontal Gain	36
	Adjustment of External Trigger Source Follower	36
	Adjustment of Sweep Timing	36
	Adjustment of Horizontal Positioning Range	36
	Setting of Vertical Regulated Supplies	36
	Calibration of Vertical Amplifier	37
	Compensation of Vertical Attenuator	38
VII	Parts List	40

TABLE OF CONTENTS (Continued)

List of Illustrations

		Page
Model 5002 Oscilloscope		1
Fig. 1.	Typical Trigger Response Curves Trigger Source - Internal	3
Fig. 2.	Typical Trigger Response Curves Trigger Source - External	3
Fig. 3.	Calibrator Display	7
Fig. 4.	Probe Squarewave Compensator	7
Fig. 5.	Measurement of AC Component Amplitude	9
Fig. 6.	Measurement of Period of Wave Form	10
Fig. 7.	Operational Block Diagram	12
Fig. 8.	Servicing Etched Circuit Boards	18
Fig. 9.	Wave Forms, Trigger Circuit Test Points	20
Fig. 10.	Sawtooth Wave Forms, Sweep Generator Circuit Test Points	21
Fig. 11.	Wave Forms, Blanking Circuit Test Points	21
Fig. 12.	Wave Forms, Calibrator Circuit Test	22
Fig. 13.	Wave Forms, Auto Circuit Test Point	22
Fig. 14.	Wave Forms, Vertical Delay Line Test Points	23
Fig. 15.	Wave Forms, Power Supply Test Points	23
Fig. 16.	Location of Subassemblies Which Show Components	25
Fig. 17.	Vertical Amplifier Upper Board (shown from outside)	26
Fig. 18.	Vertical Amplifier Upper Board (shown from inside)	27
Fig. 19.	Vertical Amplifier Lower Board	28
Fig. 20.	Horizontal Circuitry Board (resistors)	30
Fig. 21.	Horizontal Circuitry Board (other components)	30
Fig. 22.	Power Supply	31
Fig. 23.	VOLTS/DIVISION Switch, Channels A & B (viewed from top)	32
Fig. 24.	VOLTS/DIVISION Switch, Channels A & B (viewed from side)	32
Fig. 25.	VOLTS/DIVISION Switch, Channels A & B (viewed from bottom)	33
Fig. 26.	TIME/DIVISION Switch (viewed from top)	33
Fig. 27.	TIME/DIVISION Switch (viewed from bottom)	34
Fig. 28. through Fig. 35	Schematic Wiring Diagrams (8 sheets)	Back of Manual

ADDENDUM SHEET
FOR
INSTRUCTION MANUAL NO. 2490-630
SUPPLIED WITH
HICKOK MODEL 5002 AND 5002A OSCILLOSCOPES

This Instruction Manual applies to the Model 5002A as well as the Model 5002. The "A" model designation reflects changes in manufacturing and fabrication procedures which in no way affect the information contained in the manual.

The following corrections, additions, and notes apply equally to both model numbers. It is suggested that appropriate notes be made in the manual to reflect these changes.

Page 2. - Vertical Deflection System
Input —— change 27pF to 29 pF ± 1pF.

Page 26. Fig. 17
Capacitors C205, C217, and C230 are not shown.
Resistors R293 and 294 are not shown.

Page 32. Fig. 23
Rectifiers CR205 and CR206 are not shown.

Page 33. Fig. 26
Resistor R411 is not shown.

Page 34. Fig. 27
Rectifiers CR401 and CR402 are not shown.

Page 40. Parts List
Add C112. Same as C103.

Page 42. Parts List
Change CR201 thru CR204 to read CR201 thru CR206.

Page 45. Parts List
Change value of R228 from 200 ohms to 250 ohms.

Page 50. Parts List
S701, S702 change description to read "Switch, rotary, VOLTS/DIV" and p/n from "19912-653" to "19912-664".

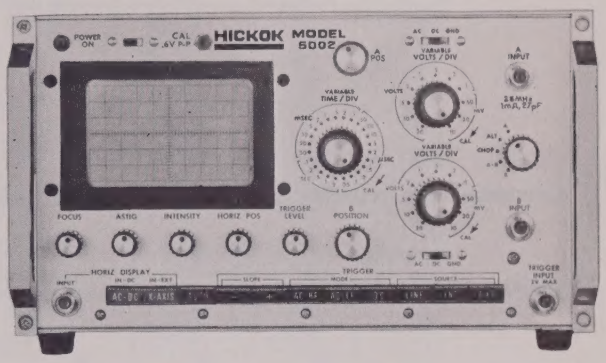
Page 50. Parts List
Booklet: change p/n from 2490-612 to 2490-630.

GENERAL INFORMATION

The Model 5002 is a versatile, rugged and compact professional oscilloscope utilizing solid-state circuitry exclusively for maximum reliability. It is designed for the display and accurate measurement of both complex and simple wave forms. Two wave forms may be displayed simultaneously and their time relationship observed, or two unrelated wave forms may be viewed separately by operating a panel switch. Response extends from DC to over 50 MHz. The 5002 may be either rack or bench mounted and removable covers allow easy access to the circuitry for calibration and troubleshooting.

The unit features a 25 MHz bandwidth to the -3dB point, calibrated vertical and horizontal sensitivities, calibrated sweep speeds, positive triggering characteristics, dual channel vertical input, and a delay line in the vertical amplifier to permit viewing of the entire leading edge of fast-rise pulses. The cathode ray tube features include a flat face, small spot size and excellent intensity characteristics. The CRT is recessed to reduce glare. Layout of panel controls combine simplicity of operation with logical grouping and retractile elevation stand permits raising the front of the unit for added viewing ease.

The extraordinary performance capability of the 5002 makes it an ideal general purpose high frequency oscilloscope for use in development laboratories, production testing and precision electronic servicing work.



Model 5002 Oscilloscope

SECTION I
SPECIFICATIONS

Cathode ray tube

Type	Brimar SE4D
Unblanking	DC coupled
Accelerating potential	3.8 kV
Usable viewing area	4.8 cm x 8 cm
Phosphor	P31
Graticule	High precision photographically etched divided into a 6 x 10 div. grid. One major division is equal to .8 cm. Major divisions are divided into five equal minor divisions. Line width of graticule is .004".

Power supplies

Line voltage	117V AC, 60 Hz nominal. Limits on input 105 to 125V AC, 50 to 65 Hz.
Power consumption	Approximately 55 watts.
Internal supplies	All internal supplies are regulated.

Mechanical

Dimensions	Width 11-1/4", height 6-7/8" from table top, depth 19" (including handles).
Weight	27 pounds.

Calibrator output

Output	0.6V peak-to-peak ±10% square wave.
Frequency	approximately 1 kHz.

Vertical deflection system

Display modes	Channel A only. Alternate: the signal on channel B is displayed alternately with that on channel A. Internal triggering is taken from channel A at all times. Chopped: the display is switched between channels at approximately 120 kHz. Internal triggering is taken from channel A at all times. A-B: the signal on channel B is subtracted from that on channel A. Internal triggering is taken from channel A. Channel B only: internal triggering is taken from channel B.
Common-mode rejection ratio in A-B mode	10:1 or greater for common-mode signals of 2 times full screen or less: for DC to 10 MHz on DC coupled input; for 5 Hz to 10 MHz on AC coupled input.
Isolation between channels	Deflection on either channel originating in the other channel will not exceed 1% of the deflection on the channel of origin, or 1/3 of a minor division, whichever is greater, at 25 MHz.
Deflection factors (each channel)	Calibrated: 10mV/Div to 20V/Div in 11 steps with 1, 2, 5 sequence. Accuracy is ±3%.
Variable attenuator (uncalibrated)	Provides continuously variable deflection factors between the calibrated steps. Extends maximum uncalibrated deflection factor to at least 50V/Div.
Positioning range	±6 divisions minimum.
Input	Selector switch provides for AC or DC coupled input or grounded amplifier input to establish the ground reference. Impedance is 1 megohm ±1% shunted by 27 pF ±1 pF.
Bandwidth	When DC coupled, at all deflection factors the upper -3dB point will exceed 25 MHz except in A-B mode, where it will exceed 22 MHz. Lower frequency response is flat to DC. When AC coupled, the low frequency -3dB point will be below 2 Hz. The high frequency response will remain the same as above. The roll-off characteristic approaches Gaussian for best pulse response.
Wave form aberrations	Less than 3% of applied wave form or 1/3 of a minor division, whichever is greater, for peak-to-peak signal up to 3 times full screen value, except as follows: With the variable attenuator near its counterclockwise extreme and within the first 20ns, less than 5%.
Maximum input for overload protection	10mV/Div: DC plus peak-to-peak AC 300V at frequencies up to 50 kHz, decreasing to 10V at 25 MHz. Other ranges: DC plus peak-to-peak AC, 500V at frequencies up to 500 kHz, decreasing to not more than 1000 times full screen value at 25 MHz.
Delay line	Provides for minimum of 50 ns of base line prior to start of a displayed pulse when triggered internally, to permit viewing of the leading edge of fast rise wave forms.

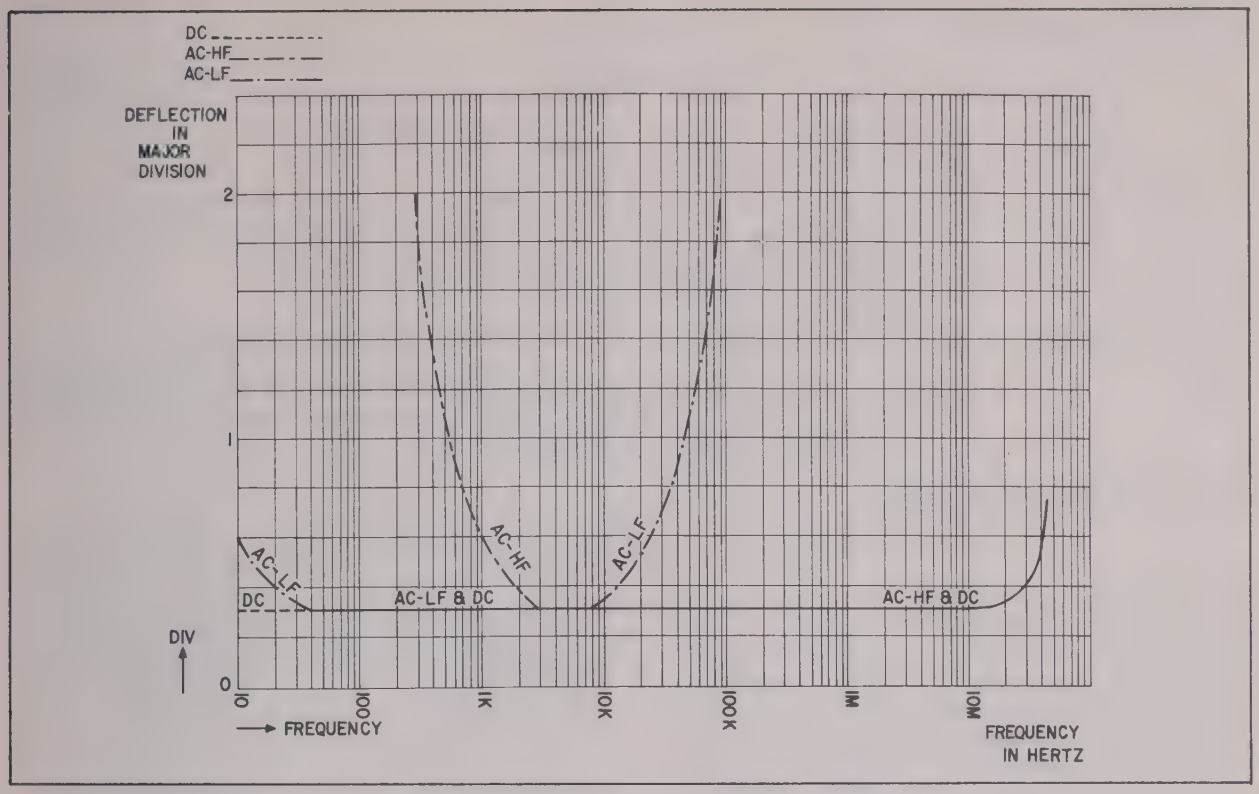


Figure 1. Typical Trigger Response Curves Trigger Source - Internal

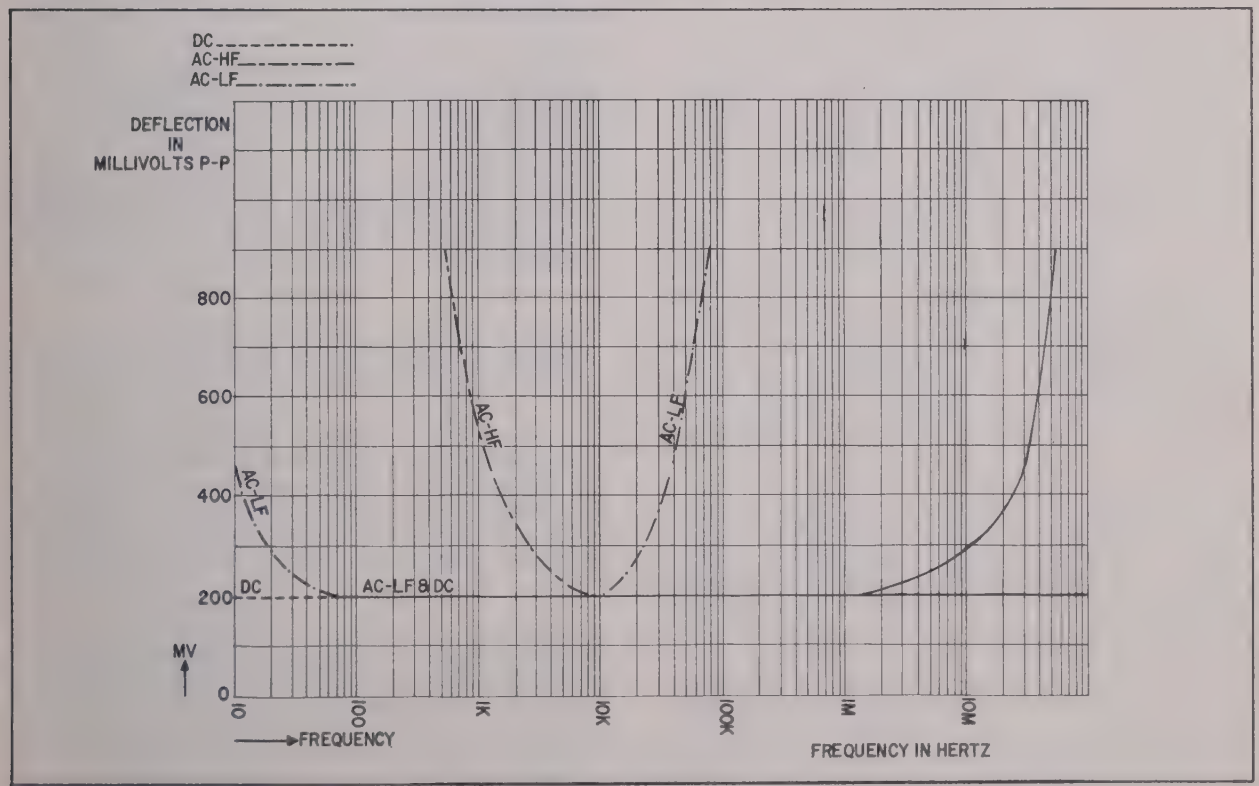


Figure 2. Typical Trigger Response Curves Trigger Source - External

Horizontal deflection system

Sweep	50 ns/Div. to 2 s/Div. in 24 ranges, in a 1, 2, 5 sequence. Calibrated accuracy for fastest 21 ranges is ±3%. Sweep speed is continuously variable between ranges.
"Sweep delay"	The sweep wave form may be delayed up to 40 divisions by means of the multi-turn HORIZ POS control, allowing the operator to obtain full screen presentation of selected portion of the input wave form or pulse train.
X-Axis amplifier	AC or DC coupled input. Bandwidth is DC to over 5 MHz when DC coupled and 5 Hz to over 5 MHz when AC coupled. The input sensitivity is 200mV ±5%. Input impedance is 1 megohm ±5% shunted by approx. 30 pF.

Trigger and trigger requirements

Slope	Either the positive or negative slope of the input wave form may be selected to start the sweep.
Automatic	Provides a free-running sweep whenever the input to the trigger circuitry is absent or of insufficient amplitude to trigger the sweep.

Trigger signal requirements

Int. (Internal Triggering)

DC mode	Sweep will trigger on approximately 1-1/2 minor divisions of deflection, rising to less than one major division at 40 MHz.
AC-LF mode	Sweep will trigger on approximately 1-1/2 minor divisions from 50 Hz to 10 kHz and rising at the low frequency and high frequency ends as shown in figure 1.
AC-HF mode	Sweep will trigger on approximately 1-1/2 minor division from 5 kHz to 10 MHz rising to less than one major division at 40 MHz and 1 kHz as shown in figure 1.

Ext. (External Triggering)

DC mode	Triggers sweep on a 200mV peak-to-peak input, rising to one volt peak-to-peak at 40 MHz. This characteristic is shown in figure 2.
AC-LF mode	Triggers sweep on 200mV peak-to-peak input, rising to .5 volt at 10 Hz and 15 kHz as shown in figure 2.
AC-HF mode	Triggers sweep on 200mV peak-to-peak input, rising to .5 volt at 1 kHz and 25 MHz as shown in figure 2. Note maximum external trigger input is 2V peak-to-peak.

Trigger input impedance	1 megohm ±5% shunted by approximately 20 pF. General trigger uncertainty is less than 5 ns. High speed signals may be synchronized to eliminate uncertainty by adjusting the horizontal position control.

SECTION II
OPERATION

WARNING

Upon receipt of the 5002, the unit should be visually inspected for physical damage. The shipping carton should be saved since it is designed to prevent damage to the cathode ray tube during shipment. DO NOT RE-SHIP WITHOUT A PROPER CARTON.

DO NOT ATTEMPT TO OPERATE THE 5002 UNTIL THE SECTION OF THIS MANUAL ON OPERATION HAS BEEN READ AND IT IS CERTAIN THAT THE LINE VOLTAGE IS 105 TO 125 VOLTS AC.

REFER TO SPECIFICATIONS FOR INPUT LIMITS.

GENERAL.

The 5002 is an instrument intended to visually display the relationships between the horizontal and vertical input signals in the same manner as a conventional graph represents the relationship between two numbers, x and y, in the rectangular co-ordinates.

The dual vertical channel feature allows two independent sets of vertical information to be displayed simultaneously with respect to the horizontal information. A cathode ray tube is used to provide a bright spot on a calibrated screen. The vertical position of the spot is determined by the voltage applied between two vertical deflection plates and the horizontal position of the spot is similarly determined by the voltage applied between two horizontal deflection plates. Since these two sets of deflection plates are at right angles to each other and independent, the location of the spot corresponds exactly to the location on a graph of the point (x, y) where x is the applied horizontal voltage and y is the applied vertical voltage.

In most cases, the voltages applied vary with time and are repetitive so that the bright dot traces out continuously the dynamic relationship and visually presents a complete graph.

Basically, five sets of front panel controls are provided: Vertical mode, vertical axis channel A, vertical axis channel B, horizontal axis, and power supply controls for the cathode ray tube so that the brightness and shape of the spot may be adjusted.

VERTICAL CONTROLS:

The vertical mode switch controls the five basic modes of operation of the 5002 vertical section. These modes are: A channel mode, Alternate mode, Chopped mode, A-B mode, and B channel mode. With the mode switch in A, voltages which are connected to A INPUT will be displayed on the CRT. With the mode switch in ALT, voltages which are connected to A and B inputs will be alternately displayed on the CRT on successive sweeps. With the mode switch in CHOP, the voltages which are connected to the A and B inputs will be simultaneously displayed by switching the CRT beam back and forth between A display and B display at a rate of approximately 120 kHz. With the mode switch in A-B, the display which results from B channel input is subtracted from the display which results from A channel input. This position is useful when examining the output of differential amplifiers.

The VOLTS/DIV control for A channel is located next to the A INPUT connector. The VOLTS/DIV control for B channel is located next to the B INPUT connector. These controls determine the amount of voltage necessary for 1 cm of vertical deflection when the VARIABLE control is in the CAL position.

The VARIABLE control allows adjustment of the vertical channel sensitivity for up to two and one-half times the VOLTS/DIV switch setting.

The displays may be moved up and down by the use of the position controls. The A POSITION control moves the A trace and the B POSITION control moves the B trace. Use of these controls enables the operator to observe portions of the display which might otherwise be off screen.

When operating in the A-B mode the B POSITION control should be centered and the A POSITION control adjusted for vertical positioning of display. With the mode switch in B POSITION, voltages which are connected to the B INPUT will be displayed.

In cases where a DC component of the input voltage is not desired, a slide switch is provided to insert a capacitor between the input voltage and the vertical display system. The same switch also allows the input voltage to be disconnected, thus providing zero volts input.

HORIZONTAL SYSTEM:

The horizontal deflection system has two basic functions. In one case, the horizontal deflection is a linear function of time and the resulting display will be a graph of vertical voltage versus time. In the other case, horizontal deflection is proportional to an externally applied voltage and a displayed graph will be observed only if the voltages applied to the horizontal and vertical systems are related to each other. Two red push buttons are provided to determine the function of the horizontal display system: depressing the red button marked X-AXIS connects the horizontal system to the adjacent BNC input connector; depressing it again will release it, and the horizontal system will function as a time base.

The horizontal deflection system as a time base

For a useful display on the screen of the cathode ray tube, the vertical signal applied and the horizontal deflection must be coherently related. This insures that the deflected spot will trace and retrace itself, reinforcing brightness. To accomplish this, horizontal deflection is initiated by a trigger pulse which is internally generated from the voltage used for vertical deflection or, if desired, from the line voltage or from some external voltage source. Three push buttons are provided to determine the trigger source: depressing the one marked INT presents the trigger pulse generator with a sample of the vertical signal; depressing the one marked LINE presents a sample of the line voltage to the trigger generator; and depressing EXT allows a signal connected to the TRIGGER INPUT BNC connector to drive the trigger pulse generator. One of the three buttons must be depressed for operation of the horizontal time base.

Because of the complexity of wave forms that may be observed, it is often necessary to filter the signal presented to the trigger pulse generator. Three push buttons are provided for this purpose: depressing AC-HF inserts a high pass filter; depressing AC-LF inserts a low pass filter but also blocks DC; depressing DC removes all filters. One of these three buttons must be depressed for proper operation.

The trigger pulse generator itself is biased by the TRIGGER LEVEL control and this control picks the amplitude level of its input signal where a pulse is generated. The trigger pulse generator operates whenever its input signal crosses the bias point set by the TRIGGER LEVEL control. The operator may start the time base on either positive or negative slope crossings by means of depressing either the button marked "+" or the one marked "-". One or the other must be depressed.

In the absence of pulses from the trigger pulse generator, the time base may be started by a free-running oscillator simply by depressing the button marked AUTO. For low trigger rates (below 60 Hz) this may interfere with normal triggering, and depressing again the AUTO button will release it.

The time base does not free-run. It is started either by a trigger pulse or by a pulse from the AUTO oscillator. Once started, the rate at which the spot is deflected from left to right is governed by the switch marked TIME/DIV and by the concentric red knob. When this VARIABLE control is fully clockwise, the sweep rate is read directly from the panel. Rotating the VARIABLE control counterclockwise from its CAL position will slow the sweep rate to allow any convenient sweep rate between calibrated points.

The HORIZ POS control allows the position of the spot to be varied along the horizontal axis from the right side of the screen to the equivalent of 40 divisions off screen to the left. Counterclockwise rotation moves the spot to the left and, consequently, the "start of sweep" moves to the left. This operation of the HORIZ POS control provides the equivalent of sweep delay since the observed portion of the time base can be made to occur up to 40 time units after the sweep has started. The HORIZ POS control also positions the spot when the X-AXIS function is in use.

The remainder of the controls are used to adjust the cathode ray tube so that spot intensity, size and focus are optimized. These controls are marked ASTIG, FOCUS and INTENSITY and normally interact to some extent. Full clockwise rotation of the INTENSITY control will cause spot size to increase the same background illumination when the spot is off screen. This is an aid in finding the spot and subsequently adjusting the vertical position or other controls to obtain a display.

OPERATIONAL CHECKS:

Operational check, A channel:

To check the 5002 for proper operation, plug power cord into 117V AC line. Note that the instrument case is connected to third wire ground. Set the front panel controls as follows:

Vertical mode switch	A
A POSITION	Centered
VARIABLE	CAL
VOLTS/DIV	.1V
AC DC GND	GND
HORIZ POS	Fully CCW
TIME/DIV	.5ms
VARIABLE	Fully CW
TRIGGER LEVEL	Centered
INT	Depressed
DC	Depressed
+	Depressed
AUTO	Depressed
X-AXIS	Out

Operational check, Alternate mode

Set the front panel controls as follows:

Vertical mode switch	ALT
A POSITION	Centered
B POSITION	Centered
VARIABLE (A)	CAL
VARIABLE (B)	CAL
VOLTS/DIV (A)	.2V
VOLTS/DIV (B)	.2V
AC DC GND (A)	DC
AC DC GND (B)	DC

Apply CAL output to A INPUT and B INPUT. Two simultaneous displays will be seen. One corresponds to A INPUT, the other corresponds to B INPUT. By varying A POSITION and B POSITION these traces are positioned vertically on the face of the CRT.

Operational check, chopped mode

Set front panel controls in the same configuration as for Operational check, Alternate mode with the exception of the vertical mode switch which is now placed in the CHOP position.

Apply CAL output to A INPUT and B INPUT. Two simultaneous displays will be seen. One corresponds to A INPUT, the other corresponds to B INPUT. By varying A POSITION and B POSITION these traces are positioned vertically on the face of the CRT.

INTENSITY	Fully CW
ASTIG	Centered
FOCUS	Centered

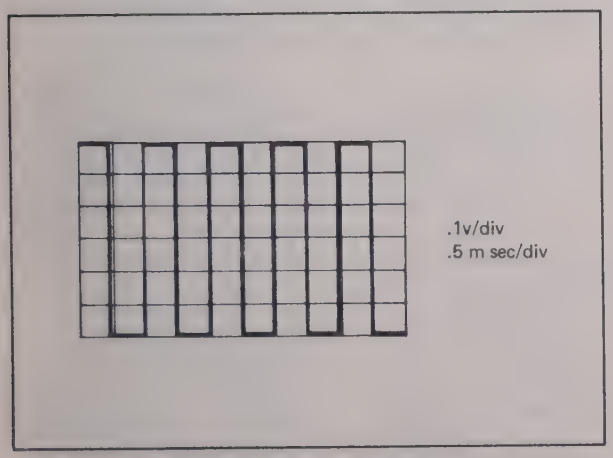


Figure 3. Calibrator Display

With the controls set as above, turn the power on and allow three minutes for warmup. A bright horizontal line should be observed.

Connect the CAL output to A INPUT connector and move slide switch to DC. Center the trace by adjusting the A POSITION control. Adjust FOCUS, ASTIG and INTENSITY controls for clean and sharp display. Rotate HORIZ POS control until the start of the sweep occurs at the first ruled line of the graticule. The display should be as in figure 3. To obtain familiarity with the 5002, the controls may be manipulated as desired and the effects observed.

Operational check, B channel

To check B channel operation, set the front panel controls as follows:

Vertical mode switch	B
B POSITION	Centered
VARIABLE	CAL
VOLTS/DIV	.1V
AC DC GND	GND

With controls set as above, a bright horizontal line should be observed.

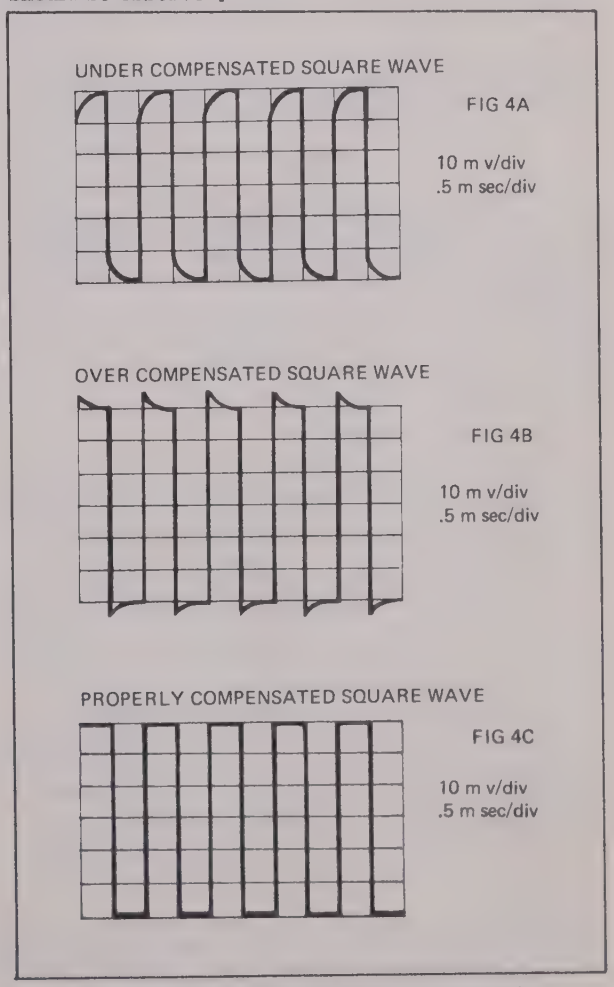


Figure 4. Probe Square Wave Compensator

Connect the CAL output to the B INPUT connector and move slide switch to DC. Center the trace by adjusting the B POSITION control. The display should be as in figure 3.

Operational check, A-B mode

Set front panel controls as for Operational check, A channel, connect the CAL output to the A INPUT and B INPUT connectors and move slide switches to DC. Center the trace with the A POSITION control. Now, move vertical mode switch to B and move B VOLTS/DIV to .5. Adjust B for 1 division of vertical deflection. Move vertical mode switch to A-B. A 5-division square wave display should result which is the information on B channel subtracted from the information in A channel.

USE OF PROBES.

Attenuator probes are frequently used to reduce resistive and capacitive loading of the circuit under test. The Hickok type 16970-87 or any standard probe which is capable of adjusting to a 27pF scope input capacity can be used. When making measurements with a probe, multiply the observed amplitude by the probe attenuation factor. The Hickok 16970-87 has a factor of 10.

To assure the accuracy of high frequency and pulse measurements, probe adjustment is necessary. To make this adjustment, proceed as follows:

1. Set the VOLTS/DIV switch to 10mV, the slide switch to DC, and connect the probe to the CAL output connector.

2. Set the TIME/DIV switch to .5ms and adjust the trigger controls for a stable display.

3. Adjust the probe for sharp rise and best flatness of the positive peak. Refer to figure 4.

SECTION III
APPLICATIONS

In this section of the instruction manual the basic procedures and techniques for making measurements with the 5002 will be described. This section is not meant to be a comprehensive text covering all possible uses of the 5002, but is intended to familiarize the user with some of the basic applications and techniques. Familiarity with the techniques and the operation of the controls will enable the operator to apply the 5002 to a wide variety of applications.

TYPICAL VOLTAGE MEASUREMENTS, SINGLE INPUT:

AC Component Measurement.

Set the vertical mode switch to either A or B, connect the signal to be observed to the corresponding panel connector, and set the AC DC GND switch to the AC position. In this position, only the AC components of the signal are displayed on the CRT. (It should be noted, however, that if the frequency of the AC component is very low the DC position should be used. If the trace is off screen, use the position control in conjunction with the VOLTS/DIV switch to obtain a trace on screen.)

To make peak-to-peak measurements of the AC component of the wave form, perform the following steps. The AUTO button should be depressed and the sweep set to some appropriate rate, dependent upon the frequency of the viewed wave form.

a. Adjust the VOLTS/DIV switch for the largest on-screen display with VARIABLE fully clockwise.

b. Depress the INT, DC and + buttons and adjust the TRIGGER LEVEL for a stable, locked display.

NOTE: If the AC component of the signal to be observed is less than approximately 3mV peak-to-peak so that reliable internal triggering is difficult, connect another signal, synchronized to the first and at least 200mV peak-to-peak, to the TRIGGER INPUT connector. Depress the EXT button. When observing small hum voltages originating from the power line, depress the LINE button.

c. Adjust the sweep rate so that several cycles of the wave form are displayed.

d. Use the appropriate vertical (A or B) and HORIZ POS controls to position the wave form to a point on the CRT where the amplitude can be easily determined. As an example, position the wave form so that one of the negative peaks coincides with one of the lower horizontal graticule lines and the positive peak occurs on the divided center vertical line.

e. Measure the vertical deflection in divisions and multiply this result by the VOLTS/DIV setting (and by the probe attenuation factor, if used). As an example of this method, assume that 5.2 divisions of deflection were used, that the VOLTS/DIV switch is set to .1 VOLTS/DIV and that a 10:1 probe was used. Thus, the calculation of the voltage amplitude would be as follows:

Vertical deflection in divisions	x	VOLTS/DIV setting	x	Probe attenuation factor	=	Volts peak-to-peak
5.2	x	.1	x	10	=	5.2 volts p-p

This example is demonstrated in figure 5.

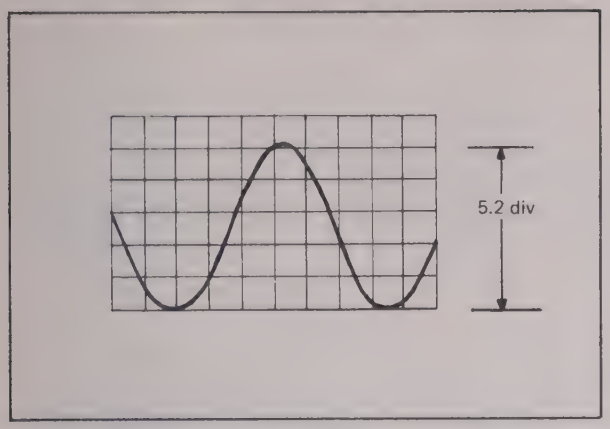


Figure 5. Measurement of AC Component Amplitude

Measurement of DC voltage level

To measure the DC level or a DC voltage level at a given point on a wave form, use the following procedure:

a. Set the TIME/DIV to 1MS/DIV and depress the AUTO button.

b. Adjust the VOLTS/DIV switch so that the voltage applied to the input connector is no more than six times the VOLTS/DIV switch setting.

c. Set the AC DC GND switch to GND and, using the appropriate vertical (A or B) position control, position the trace so that it coincides with the bottom horizontal graticule line. This point will be used as the zero voltage reference. (Note: if the signal to be measured is negative in sense, the top horizontal graticule line should be used.) Do not move the vertical position control after it has been set.

d. Set the AC DC GND switch to DC.

e. Adjust the sweep rate and trigger controls for a stable trace if there is an AC compoent present.

f. Using the HORIZ POS control, position the point on the wave form to be measured on the center vertical graticule line.

g. Measure the distance from the base reference line to the point on the wave form which crosses the center vertical graticule line and convert this reading to a voltage by the following relationship:

Deflection in divisions	x	VOLTS/DIV setting	x	Probe attenuation factor	=	Volts DC

TWO INPUTS, SEPARATELY VIEWED:

The two channels may be used to perform the above measurements on two independent signals without moving the probe connections. Two probes are used, one connected to each vertical input. To observe, move the vertical mode switch setting from A to B, resetting TRIGGER LEVEL if necessary. If the AC components of the two signals are harmonically related, however, it is more convenient to use dual-trace operation.

DIFFERENCE OF TWO INPUTS:

To measure the voltage difference between two points, as in opposite sides of a differential amplifier, use two probes, one connected to each vertical input. Set the mode switch to A-B, center the B POSITION control and use the A POSITION control to measure AC or DC voltages as above. An upscale deflection indicates that the voltage on the A INPUT is positive with respect to the voltage on B INPUT. If a higher rejection is required for signal components common to both inputs, one of the VARIABLE gain controls may be turned slightly counterclockwise to balance the gain between channels. To do this, connect both probes to a point on which the common-mode component is visible and turn whichever VARIABLE gain control provides a minimum in the amplitude on the screen. Then reconnect the probes for differential measurement.

TWO TIME-RELATED INPUTS:

Set the vertical mode switch to the ALT or CHOP position. If the signals to be viewed require slow sweep rates, the CHOP position is preferred so that the signals appear continuous. At high sweep rates, the ALT position provides a smoother trace. AC and DC voltages are measured as previously described. To avoid visual interference between the two signals, use the independent VOLTS/DIV and POSITION controls as required.

This mode of operation cannot be used to display two signals which are not synchronous or exactly harmonically related, because triggering is always from the A signal for time measurements (see below).

TYPICAL TIME MEASUREMENTS:

Measurement of pulse width

Pulse width between the 50% (or other) points of the leading and trailing edges of a pulse or similar wave form may be measured as follows:

a. Set the VOLTS/DIV switch and VARIABLE control of the channel in use to produce a deflection of exactly five major divisions, or as much as available.

b. Using the vertical position control, position the trace bottom below the center horizontal graticule line by exactly one-half (or by the percent of the amplitude of interest, if other than 50%) of the deflection. Do not adjust the vertical position control after this point.

c. Set the TIME/DIV switch so that the pulse width is no more than ten times the TIME/DIV switch setting.

d. Using the HORIZ POS control, position the leading edge of the pulse to a convenient vertical graticule line, at the point where it crosses the horizontal center line, at the left-hand side of the screen.

e. Measure the distance (in major divisions) between the point where the leading edge crosses the center horizontal graticule line and the trailing edge crosses the center horizontal graticule line.

f. Multiply this distance by the time indicated by the setting of the TIME/DIV switch to obtain the pulse width in units of time.

Measurement of pulse rise time

Rise time from the 10% to the 90% point on the leading edge of a pulse or voltage step may be measured as follows:

a. Set the VOLTS/DIV switch and VARIABLE control of the channel in use to produce a deflection of exactly five major divisions, or two and one-half divisions if five is not possible.

b. Using the vertical position control, position the trace bottom exactly 12-1/2 minor divisions below the center horizontal graticule line, or 6-1/4 minor divisions if total deflection was 2-1/2 major divisions. Do not adjust the vertical position control after this point.

c. Set the HORIZ POS control, TRIGGER LEVEL and TIME/DIV switch so that the start of sweep and entire leading edge are visible.

d. Using the HORIZ POS control, position the leading edge of the pulse to a convenient graticule line at the point where it crosses the first major horizontal line above the bottom of the trace.

e. Observe the leading edge where it crosses the first major horizontal line, counting downward from the top of the trace.

f. Measure the distance (in major divisions) horizontally, between the crossing points of steps d and e.

g. Multiply this distance by the time indicated by the setting of the TIME/DIV switch to obtain the risetime.

Measuring the period of periodic wave forms

a. Adjust the VOLTS/DIV and vertical POSITION control of the channel in use to give a trace centered about the horizontal center line of the graticule.

b. Adjust the TIME/DIV and TRIGGER controls to obtain one or more cycles of the wave form on screen.

c. Using the HORIZ POS control, position the wave form so that it crosses the junction point of a vertical graticule line on the left-hand side of the screen and the center horizontal graticule line. Note the direction in which the wave form crosses the center horizontal graticule line.

d. Measure the distance (in major divisions) from the junction point described above to where a comparable point of the next cycle of the wave form again crosses the center horizontal graticule line in the same direction as in d above.

e. Multiply this distance by the setting of the TIME/DIV switch to obtain the time duration of the period (T). This technique is demonstrated in figure 6.

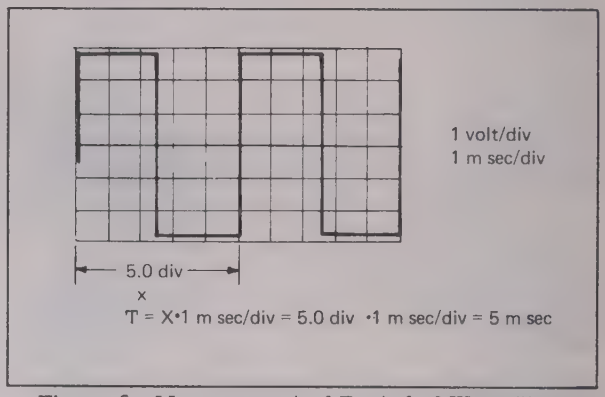


Figure 6. Measurement of Period of Wave Form

Measurement of the time difference between two signals

It is possible to measure the time difference between two signals without the need for an external trigger source, provided a signal sufficient for stable internal triggering is applied to A INPUT.

a. Connect one signal to A INPUT and the other to B INPUT.

b. Set the mode switch to ALT or CHOP and depress the INT button.

c. Set each VOLTS/DIV and VARIABLE control so that the corresponding pattern is nearly full screen or as large as possible, while setting TRIGGER controls and TIME/DIV for a stable display with both wave forms visible.

d. Position each trace so that the point of interest on the wave form is on the center horizontal graticule line.

e. Set the HORIZ POS control so that the point of interest on the A trace crosses a convenient vertical graticule line.

f. Measure the distance horizontally, in major divisions, from this point to the point of interest on the B trace, using the scale on the center horizontal line.

g. Multiply the above distance by the setting of the TIME/DIV switch. This is the time displacement required.

SECTION IV
THEORY OF OPERATION AND CIRCUIT DESCRIPTION

In this section of the instruction manual the operation of the various sections of the circuit is described. A simplified operational block diagram is presented in figure 7 and a brief description of each section is given below to explain the general operation of each circuit. A detailed description of each circuit is presented.

BLOCK DIAGRAM DESCRIPTION

Power supply

The power supply provides all operating voltages for the 5002. All supplies are regulated by the line input regulator and further regulation is provided for the -20 volt, + 20 volt, -16 volt, + 16 volt and -800 volt supplies.

Vertical amplifier

Basically, the vertical amplifier consists of the following:

1. Two separate low-level amplifiers (channel A and channel B), each having an input coupling network, an attenuator, a high impedance input stage and phase splitter, and a cascode stage.

2. A diode switching circuit which connects or disconnects each cascode from the following stages.

3. A single channel including delay line driver, delay line and two high level stages of which the second is the final amplifier.

Vertical switching multivibrator

This is a symmetrical circuit using both collector-to-base and emitter coupling. It can be operated as an astable or bistable multivibrator, or be connected so that one side conducts at all times, as required by the mode of operation chosen. It sets the levels on the switching diodes to connect one or both vertical channels.

Time base circuitry

The time base generator provides an accurate voltage ramp for the horizontal deflection system. The time base ramp may be started by signals either from internal or external sources.

Trigger circuitry

The trigger circuitry converts the input signal to a pulse which causes the gating multivibrator to change states, turning the time base generator on and the blanking off.

Horizontal amplifier

The input to the horizontal amplifier is selected from either the output of the time base generator or the horizontal display input. The input selected is split in phase by the input amplifier and is amplified to provide push-pull drive for the horizontal deflection plates.

Hold-off circuitry

The hold-off circuit samples the output of the horizontal amplifier during sweep to determine when the time base generator should be turned off and the blanking turned on.

Cathode ray tube

The cathode ray tube used in the 5002 is a 4-inch, flat-face tube with a 4.8cm and 8cm usable area. The tube is designed for minimum spot size with high intensity and minimum center to edge defocusing in both axes.

Calibrator circuit

The calibrator circuit in the 5002 is an astable multivibrator running at approximately 1 kHz. The output of the astable is used to drive a switching transistor which, through a divide, provides a fast rise time square wave with a minimum of DC offset and high amplitude stability.

The following is a detailed description of the operation of each circuit in the 5002. While reading through the description of a particular circuit, refer to the proper schematic diagram located at the end of this instruction manual and the block diagram in figure 7.

POWER SUPPLY

Line input regulation

Regulation of the power supplies in the 5002 is achieved by keeping the input voltage to the power transformer constant. This is done by limiting the peak input line voltage to a predetermined value. The peak limiting circuit consists of a power transistor (Q101), four steering diodes (CR101 through CR104) in series with the primary winding of the transformer. A voltage comparison amplifier and secondary feedback winding controls the peak limiter.

In operation, during the positive half cycle of the line input, the current path is through CR102, Q101 and CR103. During the negative half cycle the current path is through CR101, Q101 and CR104. The point at which Q101 stops conducting is determined by comparison of the voltage from a secondary feedback winding (#3-5) and a zener voltage (Q107) through a differential amplifier. When the feedback

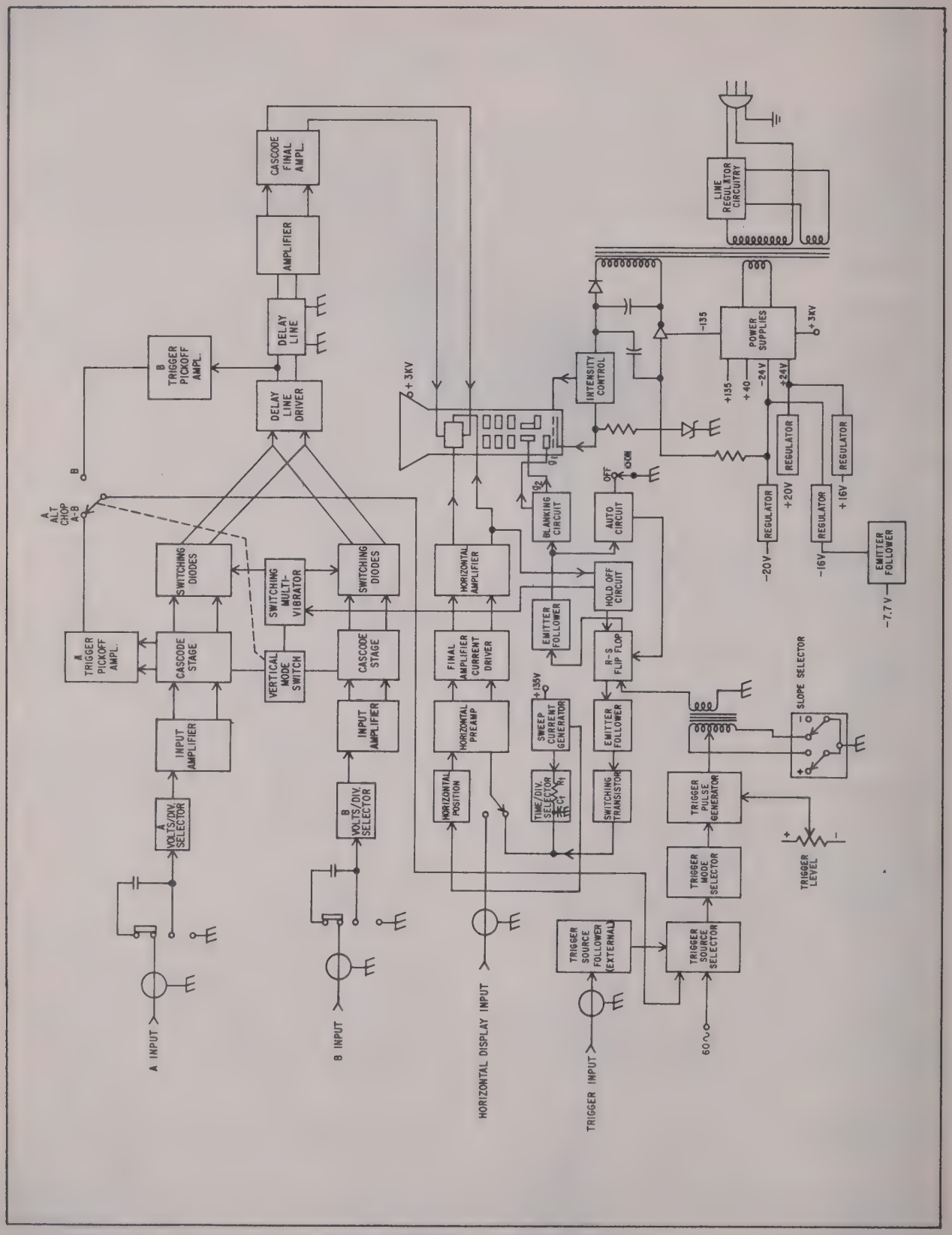


Figure 7. Operational Block Diagram

voltage exceeds the zener voltage, Q105 begins to conduct, drawing the base of Q101 out of conduction. When Q101 is not conducting, the current path to the primary winding is essentially open-circuited and no higher voltage will be developed across the primary.

The voltage feedback from the secondary winding is obtained by rectifying and capacitively filtering the output of the rectifier. Thus, the feedback voltage is derived from a peak voltage at the primary. The end of the conduction region of Q101, and thus the maximum peak voltage across the primary, is determined by the setting of R108, which determines the divide ratio from the feedback voltage.

Voltages derived from the secondary winding

The power supply delivers filtered and regulated voltages of + 24, + 40, + 135, + 3000, -24 and -800 volts. Further regulation is provided for the -800, -24 and + 24 volt supplies. A -800 volts is obtained and the output of the negative high voltage regulator is used to feed the CRT circuitry. Minus 20 and -16 volts are derived from the -24 volt supply. Plus 20 and + 16 (approximately) volts are derived from the + 24 volt supply. A common power transformer, T101, supplies the input power to each of the supplies as well as heater power to the CRT.

In operation each supply is supplied by a secondary winding. The output of each winding is rectified by silicon diodes connected in a full wave configuration, and filtered by a capacitor, with the exception of the -800V and + 3000V supplies, which are half wave rectified.

The -800V regulator is a bootstrap type of regulator. The output of this supply is sampled by an inverting amplifier connected to the bottom of the winding. Thus, when the input of the supply increases, the output of the amplifier decreases by an equal amount within its swing capability. The AC output of the supply is also coupled to the input of the amplifier, so the regulator will also smooth out the ripple voltage.

The + 16 volt and -16 volt regulated supplies, used for the low level vertical amplifier stages, are conventional, using series passing transistors and error amplifiers. The + 20 volt and -20 volt supplies are taken from the outputs of simple series regulators. The above supplies are protected from temporary short circuits such as occur when momentarily grounding a test lead. They should not be subjected to prolonged short circuits, if damage to resistors or transistors is to be avoided.

An emitter follower provides approximately -7.7 volts which is used as a clamping level in the switching circuit of the vertical amplifier as well as in the protection circuit of the input FET's.

VERTICAL AMPLIFIER SYSTEM

The part numbers refer to channel A for simplicity of discussion; the following applies to channel B if the corresponding part numbers are substituted (refer to schematic).

Input attenuator

The signal to be displayed is applied to the input amplifier via the AC DC GND switch, S703. In the DC position, the input coupling capacitor, C709, is bypassed so the input is DC coupled. In the AC position, the signal must pass through C709, which blocks the DC component. The capacitor limits the low frequency response to approximately 1.6 Hz at -3 dB. (If a probe having 9 megohms series resistance is used, this becomes 0.16 Hz.) In the GND position, the input circuit is disconnected from the amplifier and the attenuator input lead is grounded.

Attenuation

After passing through the input selector the signal passes through the VOLTS/DIV switch, S701. S701 is a four-section, 11-position rotary switch; the last two sections of the switch contain the attenuator networks corresponding to the .01V range through the .5 volt range. The first two sections contain a 100:1 attenuator that is cascaded with the previous attenuator as the switch goes through its five ranges. The output of the last section of the switch is connected electrically to the input amplifier.

In the .01 VOLTS/DIV position of the switch the input signal is connected directly to the input amplifier via an RC current-limiting network in the FET protection circuit. In the next five positions the individual attenuator networks are inserted in the circuit to provide the necessary divide of the input signal. The applied signal at the input of the protection circuit is always .01 volt for each division of deflection obtained on the CRT.

In the last five positions of the switch a 100:1 attenuator is cascaded with each of the previous divide networks to provide for deflection sensitivities of 1 VOLT/DIV through 20 VOLTS/DIV.

Each of the attenuators is a frequency compensated, resistance-capacitance network that will provide a constant voltage divide over the frequency range. At the lower frequencies the divides are primarily resistive. As the frequency of the input signal increases, the divide ratio will depend more upon the values of the capacitors used to shunt the resistive divide.

The variable capacitor at the input of each divide network provides a means for adjusting the input

capacity to a convenient value common to all positions of the switch. As a result of this adjustment, the input impedance on any attenuator position will be held constant relative to the other positions. This is especially useful when using a probe, as it will not be necessary to readjust the frequency compensation of the probe each time the range is changed.

FET input circuit

R201, R204, C201 and C204 form a compensated divider whose purpose is to allow a low value of capacitance to appear in series with the input gate, This and diode-connected Q201 prevent damaging negative transients from reaching Q202 (positive transients are dissipated through the Q202 gate-collector diode and CR201).

Input amplifier

This stage is a differential pair using a FET followed by a transistor, with feedback from the output collector to the FET source, on each side. The two sides of the amplifier are coupled through the variable attenuation control, R215, to provide paraphase coupling. The input signal is applied to the gate of Q202; a DC balancing voltage is applied to the gate of Q203. This voltage is adjusted so that no DC voltage appears across the variable attenuation control, R215, thereby minimizing a change in output level when R215 is rotated in the absence of a DC signal. The feedback resistors, R216, R217 and R220, are so proportioned that the differential output at the collectors of Q204 and Q205 is approximately balanced while the temperature shifts due to the FET's are essentially equal.

Cascode stage

This stage consists of a common emitter circuit with degeneration (Q206, Q207) followed by a common base circuit (Q212, Q213). The position control, R224, acts to change the DC emitter currents of the two sides of the common-emitter portion, in opposite directions. The internal gain calibration adjustment, R228, is part of the emitter resistance.

At the point of connection of the collector of the common emitter section to the emitter of the common base section, a small resistance is included to provide signal voltage to the trigger pickoff amplifier (Q208 through Q211); (in channel B there is no trigger pickoff at this point). The output of the common base section is connected to the switching circuit. The common base connection prevents switching voltages from feeding back to the trigger pickoff amplifier input.

Trigger pickoff amplifier (A)

All of the previous discussion of the vertical amplifier applies to both channels although references to part numbers have been to those of Channel A. An exception to this identity of channels is the presence of a low-level trigger pickoff amplifer in A channel only. This amplifier, Q208 through Q211, consists of two differential stages, one with emitter degeneration followed by one with collector-base feedback. Its output is connected to the trigger source switch for dual trace as well as channel A operation. The channel A signal therefore serves as time reference when internal triggering is chosen in dual trace operation.

Switching circuit and multivibrator

The switching circuit uses diodes which connect the output of the cascode stage for one channel at the same time that the other channel is disconnected. This condition is determined by voltage levels supplied by the multivibrator (Q312, Q313) as follows:

Mode switch in A

The emitter of Q312 is not connected to that of Q313, which is biased for cutoff so that Q312 conducts at all times, and its collector voltage is clamped slightly above ground by CR312. CR309, CR306 and CR307 conduct and hold the collectors of Q221 and Q222 at several volts more positive than required for the diodes CR308 and CR310, in the signal path, to conduct. At the same time, the collector of Q313 is sufficiently negative that CR304, CR301 and CR302 do not conduct and a portion of the collector current of Q212 and Q213 passes through CR303 and CR305, connecting channel A to the following stage.

Mode switch in B

The above conditions are reversed, with Q313 conducting at all times and channel B connected to the following stage.

Mode switch in ALT

The emitters of Q312 and Q313 are DC coupled and a bistable multivibrator is formed. At the end of each sweep a negative step at the base of Q314 is amplified and used to trigger the base of Q312 or Q313, alternately connecting channels A and B to the following stage. This causes both traces to appear to be seen simultaneously on the CRT screen at medium and high sweep speeds.

Mode switch in CHOP

The emitters of Q312 and Q313 are AC coupled by C317, forming an emitter-timed astable multivibrator which free-runs at approximately 120 kHz,

thereby switching channels independently of the sweep generator at a speed which causes two traces to appear simultaneously on the CRT screen at low and medium sweep speeds.

Mode switch in A-B

Q312 and Q313 are both cut off at all times. The collectors of Q221 and Q222 (channel B) are reverse connected to those of channel A, and the load resistors of channel B are not used, so that both channels are connected to the following stage via CR303 and CR305.

Delay line driver

The signal passed by the switching diodes is supplied, at low impedance, to the delay line by Q301 and Q302. These form a simple common-emitter stage with large emitter-resistance degeneration plus a large common resistor to minimize signal unbalance and voltage changes due to temperature, at the delay line input. Compensations for delay-line frequency response are included in the emitter circuit.

Trigger pickoff amplifier (B)

A single-ended feedback pair, Q304 and Q305, is connected to one side of the delay line input. It is temperature compensated by diode-connected Q303. The output is used for internal triggering when the mode switch is set to B.

Delay line

The delay line provides for a signal delay of 120 nanoseconds, at an input impedance of 186 ohms. Since the delay line is after the trigger pickoff amplifiers, the input signal will be displayed on screen 120 nanoseconds after the trigger system has been initiated. However, because of the inherent delay in the trigger circuitry and sweep circuitry, the end result will be that the signal will reach the trigger point on screen approximately 50 nanoseconds after the sweep has been initiated on screen.

High-level stages

Following the delay line is an amplifier stage with collector-base feedback including thermistors (RT301, RT302) which reduce the effect of temperature changes on the overall gain of the vertical amplifier.

The final stage, Q308 through Q311, is a cascode to minimize capacitive feedback. Frequency compensations are included in the emitter circuit.

HORIZONTAL AMPLIFIER

The horizontal amplifier converts the single-ended sweep ramp output of the sweep generator into an amplified push-pull signal suitable for driving the horizontal deflection plates. The amplifier consists of a preamplification stage and a final amplification stage that is connected to the horizontal deflection plate leads.

The input to the preamplifier consists of two high input impedance P-channel FET transistors, connected in a "long-tailed", paraphase configuration. The drains of these transistors are connected to the inputs of an emitter coupled differential amplifier.

The final amplifier consists of two complementary feedback pairs connected differentially to a common current source. The complementary feedback pairs are connected to the emitters of the grounded base amplifiers and provide the necessary current swing to produce the differential voltage swing required at the deflection plates.

TIME BASE

The time base consists of sweep trigger circuitry and ramp generation circuitry. The sweep trigger circuitry consists of the controls for mode, source, slope, level, trigger pulse generator, and gating circuits used to generate the start sweep pulse. The sweep or ramp generation circuitry consists of the switching transistor and associated R-C network, the current generator, hold-off, and blanking circuits.

Trigger circuit

The input to the trigger circuit is selected by the source selector; either internal, external or line frequency signals may be selected. If the external mode is selected, the input signal is coupled into a high input impedance source follower. After the source has been determined it is necessary to determine the mode of coupling the trigger signal to the input of the trigger pulse generator; either AC-HF, AC-LF or DC coupling may be selected. In the AC-HF mode, only high frequency components of the trigger signal are passed unattenuated and, similarly, only low frequency components will be passed unattenuated in the AC-LF mode. In the DC mode, however, all frequency components of the trigger signal, including DC, are passed.

From the mode selector the trigger signal is coupled to the input of the trigger pulse generator. The trigger pulse generator operates as follows:

A positive going signal is applied at the base of Q515 (an emitter follower), causing the emitter

to rise with it. At some point on the input voltage, as determined by the reference DC lever from the TRIGGER LEVEL control into the opposite side of the trigger pulse generator, Q516 will begin to conduct. (The initial assumption of proper adjustment of the TRIGGER LEVEL and a positive going signal require that Q516 be turned off.) When this happens the voltage at the collector of Q516 will begin to fall. This will cause Q520 to become forward biased and begin to draw current, which in turn will require that Q519 give up current. This causes the voltage at the collector of Q519 to fall toward ground, and the emitter follower, Q518, will also fall. This will cause the base of Q517 to begin approaching reverse bias, which in turn will cause Q517 to give up more current. This will cause Q516 to draw more current at a greater rate until the switching process is complete.

When Q520 became forward biased in the switching process, the current through the primary of T501 was changed from 0 to a current, I, in a very brief time. Thus, at the output winding of T501, a very sharp pulse will have been generated.

The polarity of the pulse out of T501 will depend upon the direction of the flux in the core. It will be noticed that there are two primaries on T501 wound in opposite directions and connected to the slope selector so that when the + button is depressed the flux path through T501 is such that the positive pulse generated in switching will coincide with the positive slope of the trigger input wave form. When the - button is depressed the positive pulse will coincide with the negative slope of the input wave form.

The output of T501 is connected to one input of a R-S (reset-set) flip-flop. When a sweep ramp is not being generated, Q524 is off and Q525 is conducting. Therefore, a positive pulse at the base of Q523 will cause it to conduct momentarily, dropping the voltage at the collector of Q524. This voltage drop will be coupled through the zener diode Q521 to the base of Q525, tending to drive it out of conduction and thus causing the regenerative switching process to take place.

Sweep ramp generation

The low output of Q524, at this point, is conducted through an emitter follower to the base of Q619, the switching transistor. This causes Q619 to be "turned off" and the timing capacitor to be charged.

A linear voltage ramp is obtained by applying a constant current from the current generator into the capacitor to satisfy the relationship $T = \frac{CV}{I}$.

Blanking circuit

The low output of Q524 is also coupled through an emitter follower, Q621, to the input of the blanking circuit. The low voltage at the base of Q614 causes the transistor to become reverse biased and the voltage at the collector to be pulled up by the momentary conduction of Q606 until it is clamped at + 78V by CR607. When the voltage at g_2 of the CRT reaches the potential at A_1, the beam is unblanked.

When the linear voltage ramp reaches the end of sweep the R-S flip-flop will be reset as explained below. This will cause the base of Q614 to be forward biased and the voltage at the collector will drop until it is clamped at + 20V by CR609 and the beam will be blanked.

The process of blanking in the CRT consists of deflecting the electron beam to the side so it will no longer pass through an aperture. This will cause the electron beam not to appear on screen. When the electron beam is unblanked, it will not be deflected and will appear on screen.

Two plates, one on each side of the beam, deflect or blank the electron beam when there is a 56V difference in potential between the two plates. To unblank the beam, the potential of the two plates must be equal.

Hold-off circuit

The hold-off circuit samples the output of the horizontal amplifier to sense the turn-off point on the sweep wave form. The hold-off circuit consists of a Schmitt trigger (Q528, Q529 and Q530) which is driven by an emitter follower, Q527. The output of the Schmitt trigger is coupled to the reset of the R-S flip-flop, at the base of Q526. A positive output from the hold-off circuit will cause the R-S flip-flop to be reset. This turns on the blanking circuit (see preceding paragraph on the operation of the blanking circuit) and at the same time causes Q619, the sweep generator, to be forward biased, discharging the timing capacitor.

In operation, the sawtooth sampled at the collector of Q514, as it approaches saturation, connects the diode, CR508, and draws down the input to the emitter follower, Q527. As the output voltage of the follower decreases, the input transistor of the Schmitt trigger, Q528, is forward biased and regenerative switching takes place. At this point, Q619 is forward biased and the timing capacitor discharged through Q619.

The sawtooth, in the process of driving the base of Q527, will cause the hold-off capacitor to be discharged. As the timing capacitor discharges, the voltage at the collector of Q514 will rise to a positive voltage, close to the + 135V supply, causing the horizontal amplifier output to disconnect from the hold-off circuit. When this occurs the hold-off capacitor connected between the base of Q527 and ground will begin to charge positively. When the voltage at the emitter of Q527 reaches the point where Q528 is reverse biased, the Schmitt trigger switches states, uninhibiting the R-S flip-flop and allowing it to accept the trigger pulses applied on the set side. Thus, it is necessary to provide sufficient hold-off time to allow Q619 to discharge the timing capacitor completely, or erratic sweep behavior and locking characteristics will be observed.

SECTION V
SERVICE PROCEDURE

As an aid to servicing your unit, photographs showing physical location of components are included in figures 16 through 27. These carry the same symbol designations as the schematics and parts list and are included in the instruction book at the end of this section.

WARNING

1. Precautions against shock should be taken when the covers are removed, as all supplies, voltages and line will be exposed.
2. To prevent damage to line regulator and/or operator from accidental shock, do not operate the unit with the rear panel removed from the side frames.
3. If it is necessary to service the power supply, note that the case of Q101 is at line potential. Be careful not to short the case to ground either by contact with the side frame or through the operator. In both cases extensive damage may be the result.
4. When servicing the power supply, use an isolation transformer so that accidental grounding of the power line by test equipment ground does not occur.

GENERAL:

Normally, the Model 5002 will not require service for extended periods of time; however, if service is required, it is recommended that only qualified individuals, thoroughly familiar with transistor circuit operation, undertake such service. The Hickok Electrical Instrument Company maintains a complete factory service department, backed by authorized factory repair stations, to assure prompt service for this instrument.

If it is necessary to repair the instrument in the field, it is imperative that the section covering the theory of operation be read and understood before proceeding. It is also important to use a logical approach to localize circuit failures, as indiscriminate replacement of components could cause damage to the board or perfectly good components. The Procedure for Replacing Components in Printed Circuit Boards, outlined in figure 8, should be followed rigorously in order to prevent damage to components or printed circuit board.

To remove cover panels

WARNING: Do not plug the unit into power line during this procedure.

To remove the covers, first remove the four screws holding the trim pieces to the rear panel. After the two rear panel trim pieces have been removed, four additional screws will be exposed; remove these screws and lay the panel on the bench. Next slide out the top cover and the two side covers. Carefully turn the unit over and remove the single screw near the rear-center of the bottom cover and slide the bottom cover out. Before proceeding, replace the rear panel and secure with the screws to the side frames. Normal precautions against shock should be taken, since once the covers are removed all power supplies are exposed.

Recalibration

To insure accurate measurements, check the calibration of the instrument periodically. Complete calibration instructions are given in Section VI.

Visual inspection

Inspect the 5002 periodically for such defects as broken connections and leads, and heat-damaged components. The unit should also be inspected for excessive accumulation of dust on heat-dissipating elements and the dust removed.

CRT trace alignment

If it should become necessary to align the CRT trace, proceed as follows:

(1) Remove the cap covering the TRACE TILT ADJUST hole in the top of the instrument case.

(2) Use a medium blade screwdriver to turn the adjustment screw for proper trace alignment.

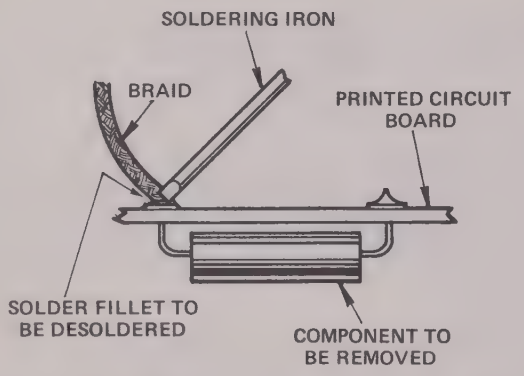
NOTE

TRACE SHOULD BE PARALLEL WITH HORIZONTAL GRATICULE LINES.

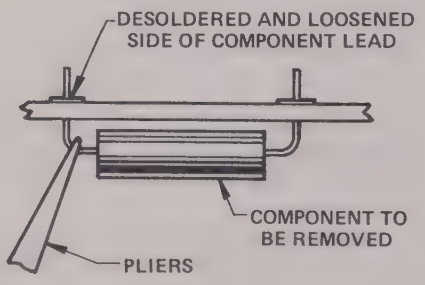
PROCEDURE FOR REPLACING COMPONENTS IN PRINTED CIRCUIT BOARDS

1. Place printed circuit in the horizontal position with the soldered side up*. Take a length of fine braid or fine stranded wire either tinned or not tinned. Braid is preferable. Dip the end of the braid in resin flux (London Chemical Co. type #77-33-TA or equivalent). Placed the fluxed end of the braid on a solder fillet of the component to be removed. Press the braid on to the fillet using the clean tip of the soldering iron. Do not overheat the board or component. Only heat the solder fillet sufficient to melt the solder. The solder will "wick" up the braided wire removing the solder from the joint. Continue this process until all leads of the component to be removed are free of solder.

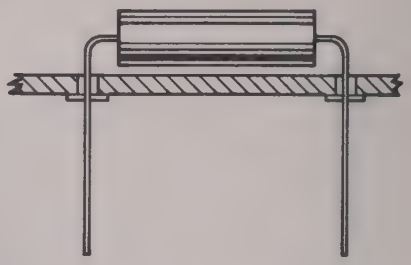
*A SOLDAPULLT desoldering tool, manufactured by Edsyn Inc., can be used in place of standard wire.



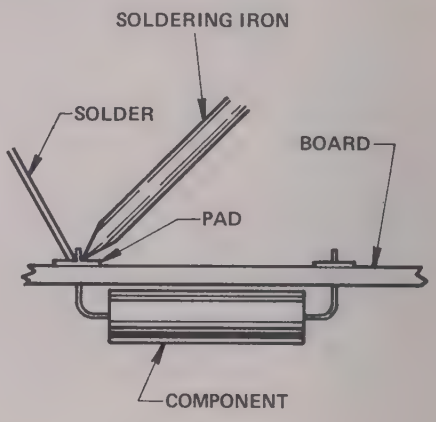
2. Using a pair of needle nose pliers "wiggle" each lead of the component to be removed to be sure it is free of the land area to which it was soldered. Place the needle nose pliers on the component lead and remove the lead. Continue the procedure with each component lead until the component is removed. Do not force the leads. If a lead can not be removed touch the lead on the soldered side of the board with the soldering tip.



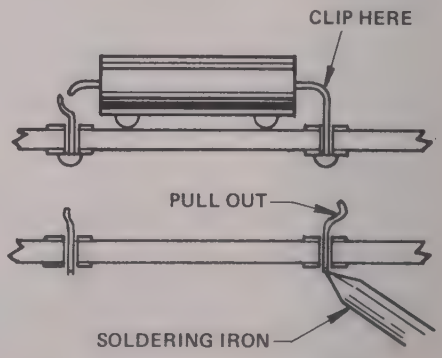
3. Bend clean tinned leads of new component and carefully insert in holes. (Do not force component. If it does not insert easily reheat pad and clean as before).



4. Hold part to board and solder leads from print side of board. Do not leave a large blob of solder on pad. The correct amount can be determined by observing other connections made in production.



Clean holes with a piece of .020 stainless steel wire by melting the solder and poking the wire through.'



The above should be carefully followed or extensive damage to the printed circuit board will result.

Figure 8. Servicing Etched Circuit Board

To replace cathode ray tube

To remove and replace the cathode ray tube, use the following procedure:

1. Using a Phillips head screwdriver, remove top cross brace.

2. Remove rear panel and lay it down on bench.

3. Remove the CRT anode lead, all leads from the neck of the CRT, and the rear socket connector.

4. Using a Phillips head screwdriver, remove the two screws on the left side frame mounting the CRT retaining bracket.

5. Lift the CRT assembly back and out of the unit.

6. Loosen the clamp holding the neck shield and pull the tube free of the shield assembly.

7. The neck shield is potted to the CRT with General Electric RTV-112 adhesive. After removal of the neck shield from the tube the excess compound can be removed from the shield by soaking in a strong chlorinated solvent.

NOTE: The neck shield should be repotted on the new CRT in order to provide proper clamping of the CRT.

TROUBLESHOOTING:

The first step in repair of the unit should be to localize the problems to a general area of the circuitry such as the vertical amplifier, trigger circuitry, etc. This can generally be accomplished by observing the performance of the unit. As an aid to the localization of the problem area, it is helpful to think of the unit as divided into twelve major areas of circuitry. For the 5002 these are as follows:

1. Trigger circuitry
2. Sweep generator
3. Blanking circuit
4. Horizontal amplifier
5. Vertical channel A, up to switching
6. Vertical channel B, up to switching
7. Vertical switching and multivibrator
8. Vertical amplifier after switching
9. Delay line
10. Power supplies
11. CRT circuitry
12. Calibrator

The 5002, as with all highly accurate instruments, will require periodic recalibration checks in order to insure a high degree of accuracy. Occasionally, circuits out of calibration may cause apparent trouble symptoms. For this reason, check the calibration of the unit before proceeding with a detailed trouble analysis; also, a calibration check will greatly aid in localizing circuit failures. The calibration procedure is found in Section VI of this instruction book.

In the event trouble develops, check all the obvious possibilities first, such as the following:

1. The line cord is plugged in and there is power at the receptacle.

2. The fuse is good; note that the pilot lamp lights when the power switch is turned on.

3. All the front panel controls are set properly for the desired operation.

Then adjust the panel controls through their range and observe the operation in an attempt to localize the problem to a particular section of the circuitry. . The normal or abnormal operation of a particular control will aid in localizing the trouble.

Since the 5002 is an extremely complex instrument, a comprehensive troubleshooting procedure is beyond the scope of this text. In general, trouble-shooting an instrument can be divided into two parts: isolating or localizing the trouble to a particular circuit, and the actual location of the defective component. The first step, isolation to a particular circuit, is covered in a general manner in the paragraphs above. Reference to figure 7, the Simplified Operational Block Diagram, and the theory of operation will further aid in localizing the trouble.

After the trouble has been isolated to a particular circuit, perform a complete visual check of that circuit for faulty components. If a visual check of the circuit fails to detect the trouble, it will be necessary to check the circuit for its electrical operating characteristics. As an aid to this procedure, the voltages and wave forms at the various test points are presented at the end of this section.

Trigger circuitry

Trigger circuit troubles are indicated by an inability to lock the trace and by erratic triggering of the sweep. The first step in troubleshooting this section is to check for the presence of an input signal to the trigger circuit at the base of Q515. If a signal is present at Q515 base, check for the

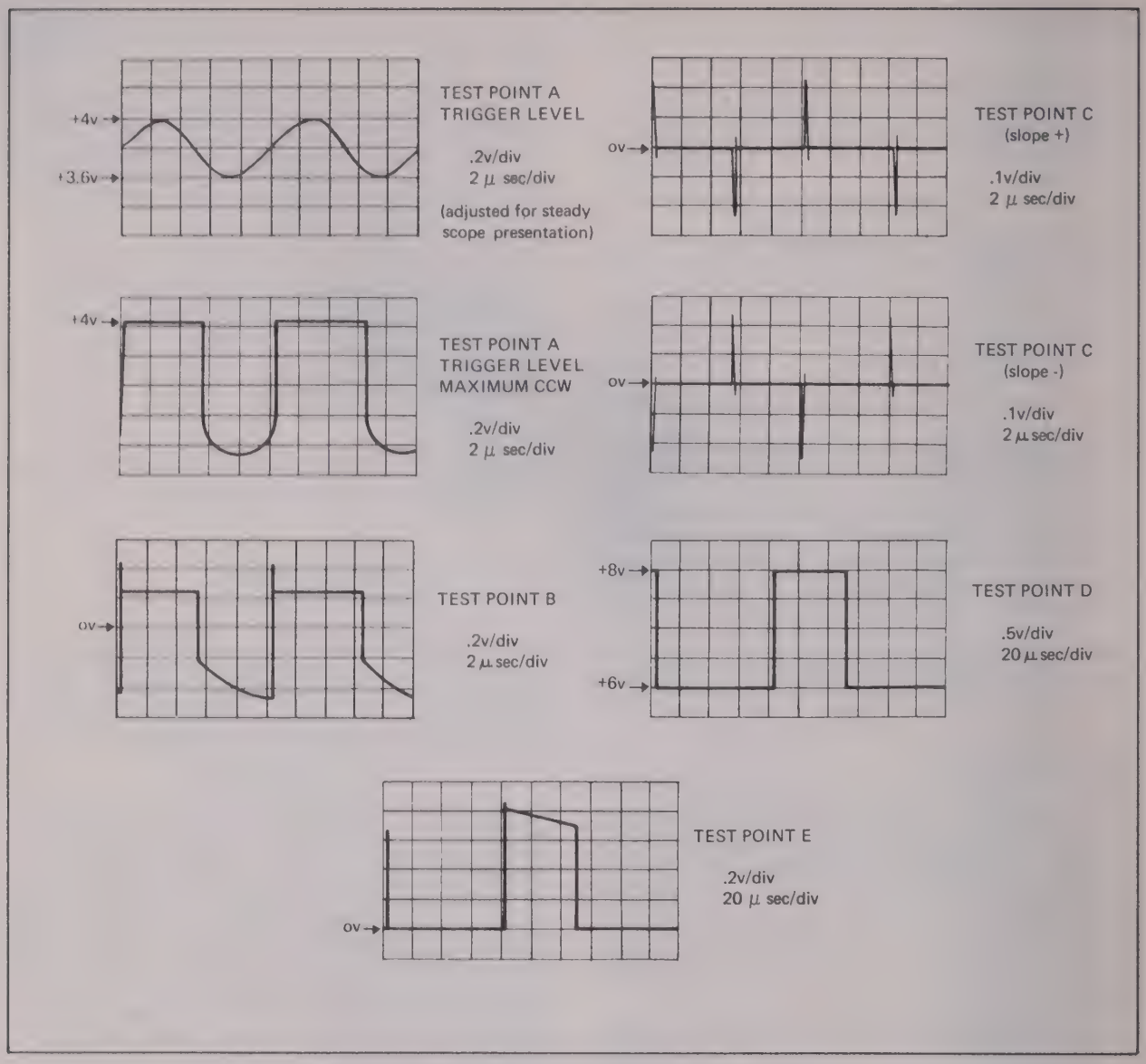


Figure 9. Wave Forms, Trigger Circuit Test Points

proper operation of each section of the trigger circuit. Typical wave forms and voltage levels for the test points on schematic "Horizontal Board - Section A" are given in figure 9.

If no triggered trace is obtained and all sections of the trigger circuit are operational, go to the sections outlining the sweep generator and blanking circuit.

Sweep generator

Troubles in the sweep generator are generally indicated by either large amounts of line frequency modulation in the horizontal direction or by no sweep being generated.

If line modulation is the problem the trouble can be traced to the sweep current generator which consists of the circuitry associated with Q616 and Q617. Typically, the ripple voltage at the output side of R663 is 10 to 20mV peak-to-peak. Check the calibration of the sweep timing before proceeding to check for faulty components.

If the problem is apparently the lack of a generated sweep, first check at test point L. A sawtooth wave form as indicated in figure 10 should be obtained. If this wave form is present, check for the signal at the input of the horizontal amplifier. If, however, no sawtooth was detected at test point L, check for the presence of a gating pulse at test point

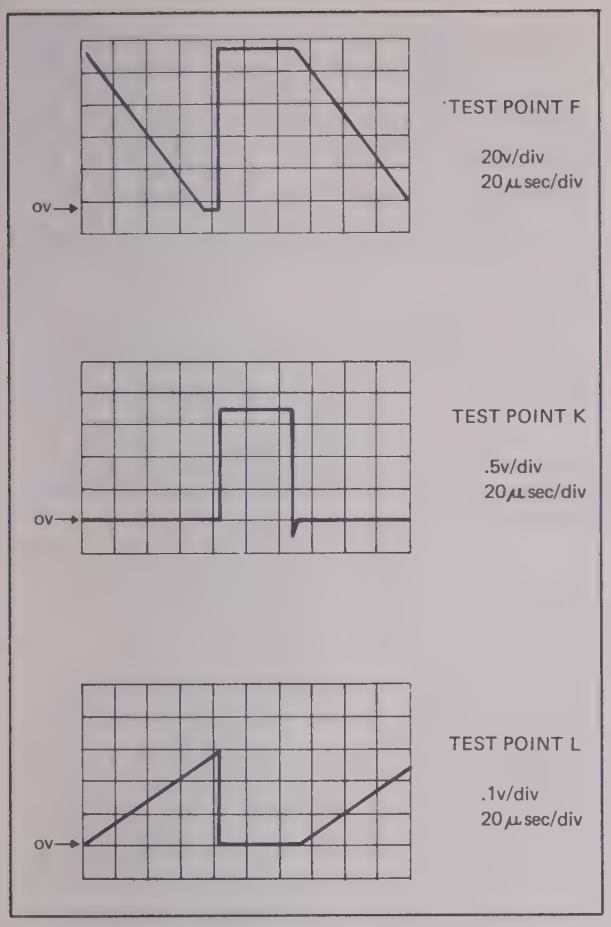


Figure 10. Sawtooth Wave Forms, Sweep Generator Circuit Test Points

K. The wave form seen at this point should be similar to that shown in figure 10. If the gating pulse is present, Q619 will have to be replaced; if not, check for the presence of the gating pulse at the base of Q618. Not detecting a gate signal at the base of Q616 indicates that the problem is located in the trigger circuitry and the procedures outlined in that section should be repeated.

Blanking circuit

Blanking circuit problems are generally indicated by an absence of trace or by a lack of blanking. A lack of blanking will be indicated at the lower sweep speeds by a vertical trace at the start of sweep.

The CRT will be blanked when the voltage at test point H is low (approximately + 20V) and a trace should be obtained when test point H is at approximately + 78V. A typical blanking wave form is shown in figure 11.

Horizontal amplifier

The problem of outlining a definite troubleshooting procedure for an amplifier is very complex. However, the basic problem is the same as found in troubleshooting any circuit: first, to isolate the problem to a particular stage and then to isolate the particular faulty component. One technique that provides very quick results in isolating the problem to a particular stage in a differential amplifier, such as used in the 5002, is to use a jumper to short the outputs of each stage together. To use this technique, it must first be determined whether the trace is centered vertically. To accomplish this, measure with a voltmeter the potentials at the collectors of Q310 and Q311, then using the vertical positioning control, set the voltages read at the collectors of Q310 and Q311 equal to each other. Next, depress the X-AXIS button and turn the INTENSITY control fully clockwise (to maximum intensity). Then use the jumper to short the collectors of Q511 to Q514. At this point the spot should appear near the center of the graticule. If the spot does not appear, check the connectors to the horizontal deflection plates of the CRT and then check the CRT. If the spot does appear, move the jumper to the emitters of Q511 and Q514. If the spot does not appear, check Q511 and Q514. Next, move the jumper to the bases of Q519 and Q512. If the spot does not appear, check the voltage levels around this section of the amplifier. Thus, it is seen that the technique consists of merely shorting the outputs of the amplifier stages together, proceeding from the output of the

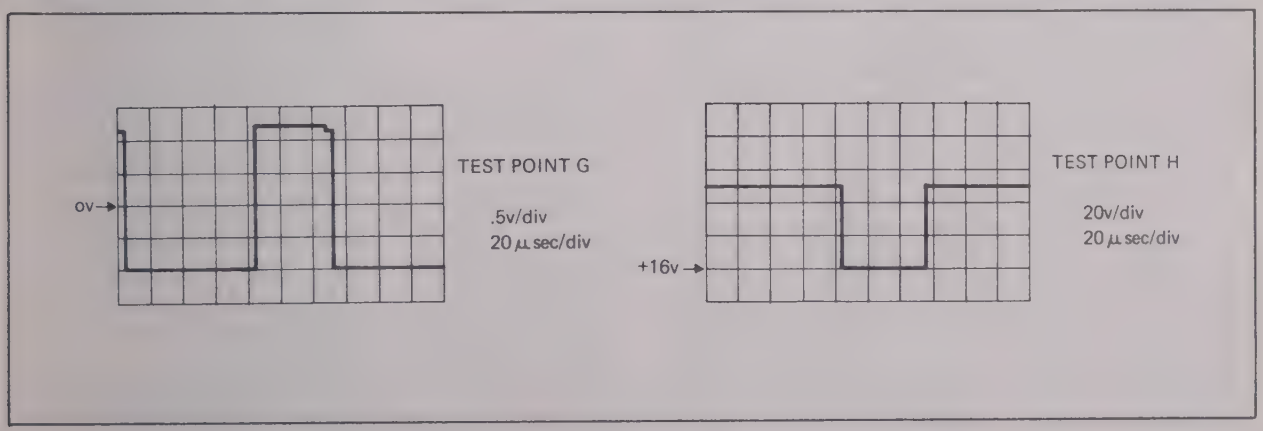


Figure 11. Wave Forms, Blanking Circuit Test Points

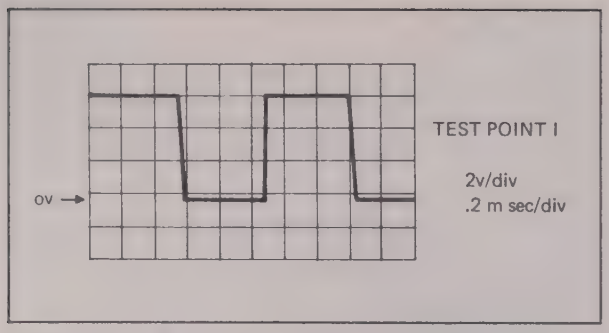


Figure 12. Wave Forms, Calibrator Circuit Point

final to the input of the first stage. The point at which the spot does not occur indicates that the trouble lies in the previous stage.

After the trouble has been localized to a particular stage, ordinary techniques may be used for pinpointing the problem to a particular component.

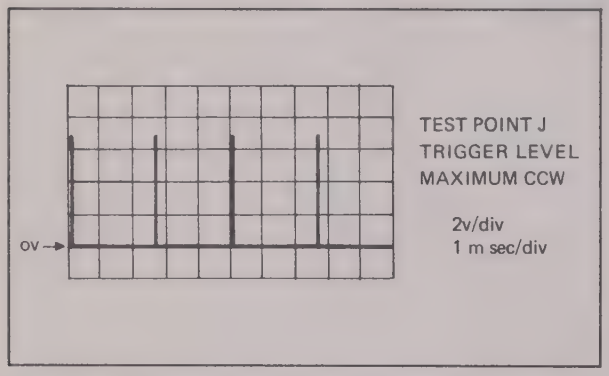


Figure 13. Wave Forms, Auto Circuit Test Point

Vertical amplifier

If power supply ripple appears on both channels or if signal from one channel appears on the trace of the other channel, first check the + 24, -24, + 15.75 and -16 volt test points for indicated voltage. Ripple is normally less than 0.6 volt peak-to-peak on the 24-volt supplies or 5mV at + and -16 volt points; abnormally high ripple indicates trouble in the regulating circuits or in the unregulated 24-volt supplies. These should read at least 22.5 volts. The + 15.75 and -16 volt points should show less than 0.02 volt change when temporarily shunted by a 1000-ohm resistor.

If the trace is far off center, if gain is well below normal, or if sine wave distortion or square wave tilt occurs, first observe whether the trouble is common to both channels. If so, and unless power supplies are at fault, the trouble should be sought in the common stages. If one channel operates properly, check that portion of the other channel ahead of the switching diodes. Trouble in the diodes or in the multivibrator may affect only one or both channels. Normal multivibrator voltages are given later in this section.

The jumper technique outlined under Horizontal amplifier may be used to isolate faulty stages in the vertical amplifier. Tables for the common portion (after the switching circuit) and for each channel (ahead of the switching circuit) are given below. The points to be shorted together are given along with the stage at fault if the spot does not appear. Before using the jumper test, use a voltmeter and the HORIZ POS control to equalize the DC voltage at the collectors of Q514 and Q511 with X-AXIS button depressed.

TABLE I. TROUBLE SHOOTING DIFFERENTIAL AMPLIFIER: AFTER SWITCHING

Short together	Problem localized to following transistors or associated resistors
Collector Q310 to collector Q311	CRT or connections to CRT
Collector Q308 to collector Q309	Q310, Q311
Collector Q306 to collector Q307	Q308, Q309
Delay line output connections	Q306, Q307
Collector Q301 to collector Q302	Delay line - see section on delay line
Base Q301 to base Q302	Q301, Q302

TABLE II. TROUBLE SHOOTING DIFFERENTIAL AMPLIFIER: Channel A

Short together	Problem localized to following transistors or associated resistors
Collector Q206 to collector Q207	Q212, Q213, switching diodes
Collector Q204 to collector Q205	Q206, Q207 If spot does appear in this step, fault is in the stage Q202 through Q205; check voltages at test point

TABLE III. TROUBLE SHOOTING DIFFERENTIAL: AMPLIFIER: Channel B

Short together	Problem localized
Collector Q219 to collector Q220	Q221, Q222, switching diodes
Collector Q217 to collector Q218	Q219, Q220 If spot does appear in this step, fault is in the stage Q215 through Q218; check voltages at test points

In some cases, a defective transistor may cause loss of high frequency response or wave form faults without causing a serious DC unbalance (spot off screen). Since compensation circuits are used in several stages to correct the frequency response of the delay line, a perfect square wave does not exist at all points in the amplifier. Therefore, if square wave problems occur in one channel only, a test scope with 10:1 probe may be used to roughly compare the two channels at various points, using the same input to both channels; but rise time and pulse response must be expected to be affected by connecting the probe. If the wave form in the amplifier following the switching circuit is observed, it will also be necessary to allow for effects due to the compensation circuits.

Substitution of transistors should correct a problem once a faulty stage has been isolated; however, the input stage FETs should be changed only in matched pairs.

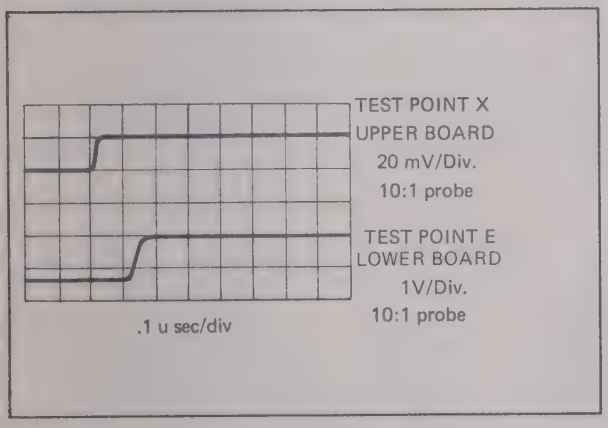


Figure 14. Wave Forms, Vertical Delay Line Test Points

Delay line

Ordinarily, without rough treatment, the delay line should not fail. However, if the test procedure of the previous section indicates that the trouble is in the delay line, check the external connections visually and then lift one of the input sides out of the circuit; jumper the bases of Q306 and Q307 and, using an ohmmeter, check the resistance from one input side to the other. The reading should be approximately 190 ohms unless the delay line has become shorted.

If the delay line proves to be shorted, pull a few turns of the leads out of both ends, one at a time, until the short disappears. Then re-dress the leads and re-install the delay line.

CAUTION: Removing the spirally wound conductor will reduce the delay time and it is recommended that a new delay line be purchased if more than 2" of lead has been removed.

Power Supplies

The circuitry connected to the secondary side of the transformer is the normal type found in various types of equipment and standard troubleshooting procedures will quickly isolate faulty components.

The circuitry on the primary side, however, must be treated with care in order to prevent damage to the operator or further damage to the circuitry. It is suggested that the line input of the 5002 be connected to an isolation transformer before any test measurements are made to prevent accidental grounding of the line input. A thorough understanding of the operation of the line regulator and the test voltages at point E and D will greatly aid in troubleshooting the supply.

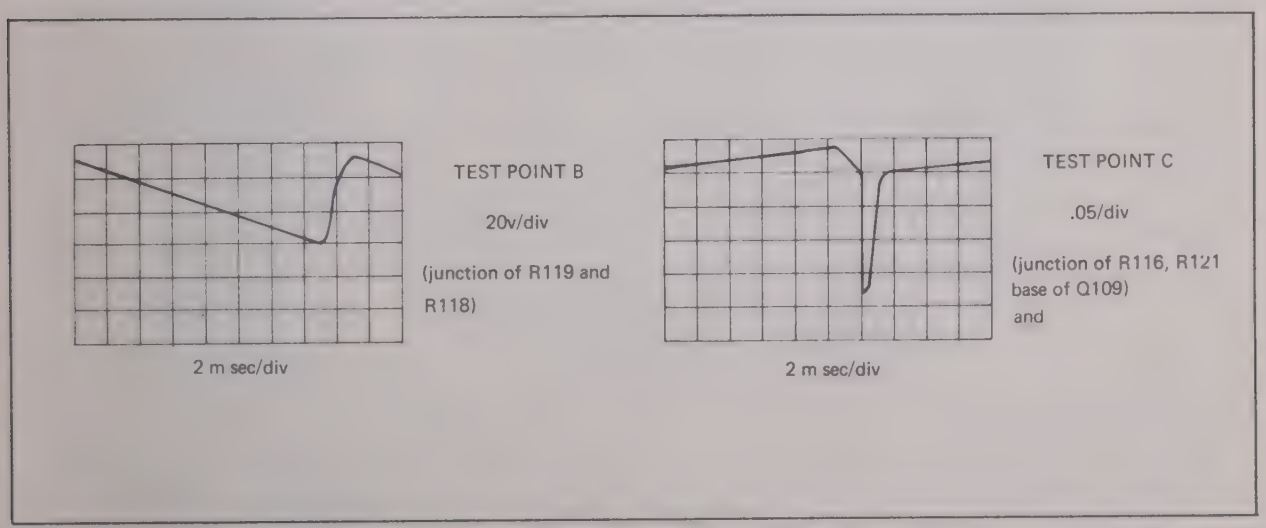


Figure 15. Wave Forms, Power Supply Test Points

Horizontal board wave forms:

The following wave forms shown in this folder were observed with an input, 100 kHz sinusoidal wave, of 1 volt amplitude. The 5002 controls were preset as follows:

AUTO	Depressed
SLOPE	+ depressed
DC	Depressed
INT	Depressed
TIME/DIV	5 μs/DIV
VOLTS/DIV	Set to 1V/DIV

Adjust trigger for steady scope presentation.

HORIZ POS	Adjusted so that start of sweep is at the first vertical graticule line

Make adjustments to trigger and horizontal controls as called out in the following figures.

The test scope was triggered externally from the trigger pulse generator in figure 9 at the collector of Q520 to obtain the wave forms shown and from the R-S flip-flop in figure 10. The trigger control settings were as follows: EXT, negative slope, DC coupling mode. The vertical VOLTS/DIV settings and the TIME/DIV settings are as noted beside each figure. Either the ground reference line or the peak voltage is also indicated for each figure to relate the wave form to the appropriate DC level at the particular test point.

Vertical test points

The voltage levers for these test points are given with the A POSITION control centered with mode switch at A, or the B POSITION control centered with mode switch at B.

The front panel controls are preset as follows:

AC DC GND (both channels)	AC
VOLTS/DIV (both channels)	10mV
TIME/DIV	.1 μ SEC
HORIZ POS	Adjust to center
A and B POSITION	Dots straight up
AUTO	Depressed
SLOPE	+ depressed
MODE (trigger)	DC depressed
SOURCE	INT depressed

ALL VOLTAGES MEASURED BETWEEN TEST POINTS AND GROUND.

TABLE IV. VERTICAL TEST POINT VOLTAGES

LOWER BOARD (to rear of horizontal board) (within ±0.5 volt unless noted)	
Test Point	Volts
A, B	-1.8 ± 0.2
C, D	-5.2 ±1
E, F	+ 22 ±5
G	+ 23 ±1.5
H	-21.5 ±1.5
I	-11.5 ±1 (mode A or A-B)
	-5.4 (ALT or CHOP)
	+ 0.7 ± 0.2 (mode in B)
J	-11.5 ± 1 (mode in B or A-B)
	-5.4 (mode in B or A-B)
	+0.7 ± 0.2 (mode in A)
K	-16 ±0.2
L	+ 15.8
UPPER BOARD (right-hand side of scope) (within ±0.5 volt unless noted)	
Test Point	Volts
A	0 ±1mV
B	+ 1.2
C	reading same as B
D, E	+ 10 ±2
F, G	+ 4.7
H, I	0 (after slight adjustment of A POSITION, if required)
J	-7.7
K	0 ±1mV
L	+ 1.2
M	reading same as L
N, O	+ 10 ±2
P, Q	+ 4.7
R, S	-4.5 (mode in A or A-B)
	-2.6 (ALT or CHOP)
	-0.7 (mode in B)
T, U	-4.5 (mode in B)
	0 (mode in A-B)
	-2.6 (ALT or CHOP)
	-0.7 (mode in A)
V, W	-3.8
X, Y	-1.4 ± 0.2
Z	0 (after slight adjustment of B POSITION if required) with mode switch set to B

Delay wave form

The delay from delay line input to CRT is shown in figure 14. This was done by connecting a fast-rise square wave signal to A INPUT and setting the amplitude and VOLTS/DIV switch for 0.2 volt at test point X on the upper board, using a dual-trace scope and two 10:1 probes.

Power supply test points

For correct readings at these test points, adjust the preregulator so that positive 135 is read at test point A on the power supply. Also adjust the minus 800 supply for proper regulation. (See Calibration Procedure, Section VI.)

Test point A: + 135V

Test point B: -33V DC level

(See figure 15 for wave form)

Test point C: -1.15V DC level

(See figure 15 for wave form)

NOTE: TEST POINTS D AND E ARE MEASURED IN REFERENCE TO THE POSITIVE SIDE OF CAPACITOR C102.

Test point D: -.5V

Test point E: + 15V

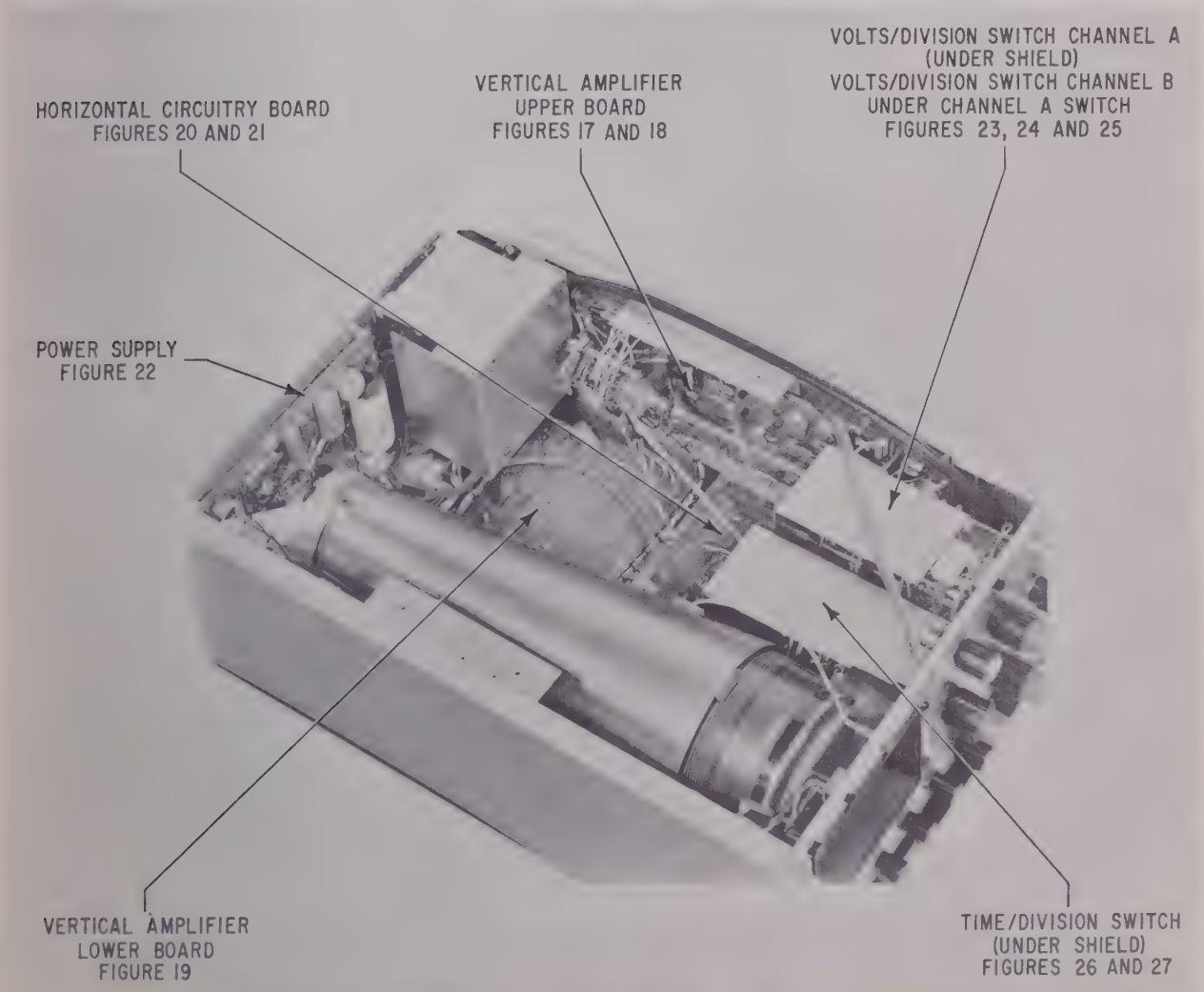


Figure 16. Location of Subassemblies Which Show Components

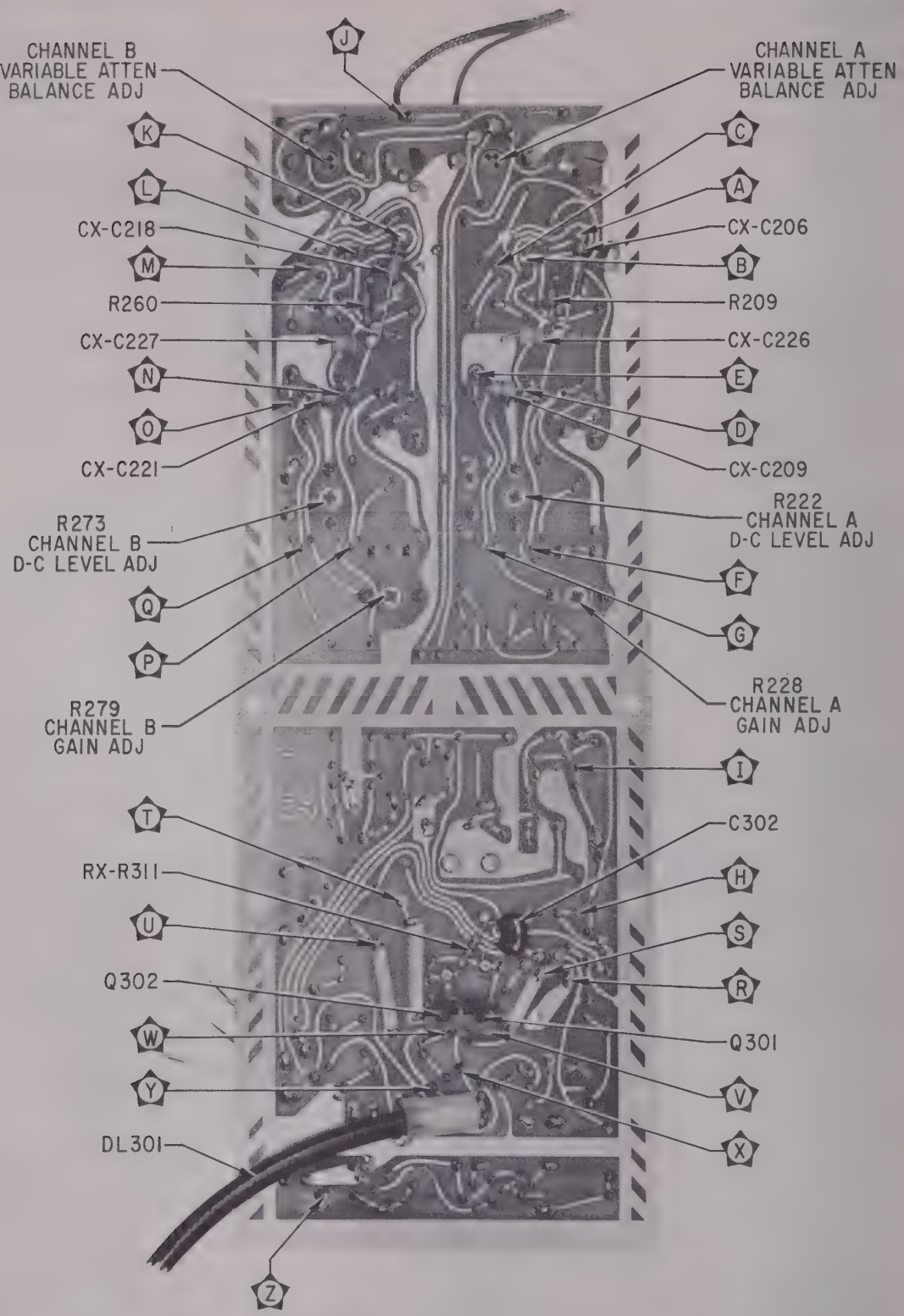


Figure 17. Vertical Amplifier Upper Board (shown from outside)

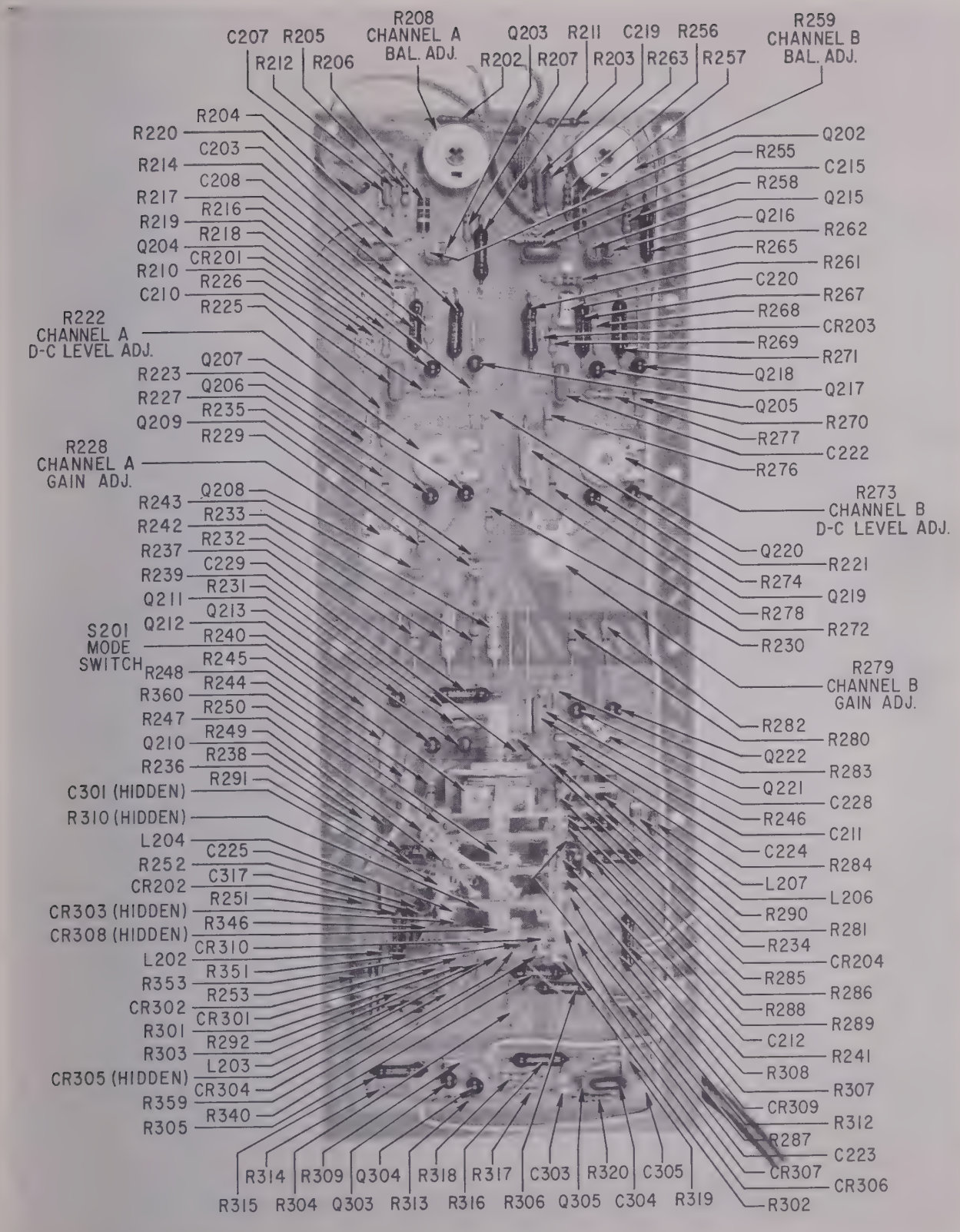


Figure 18. Vertical Amplifier Upper Board (shown from inside)

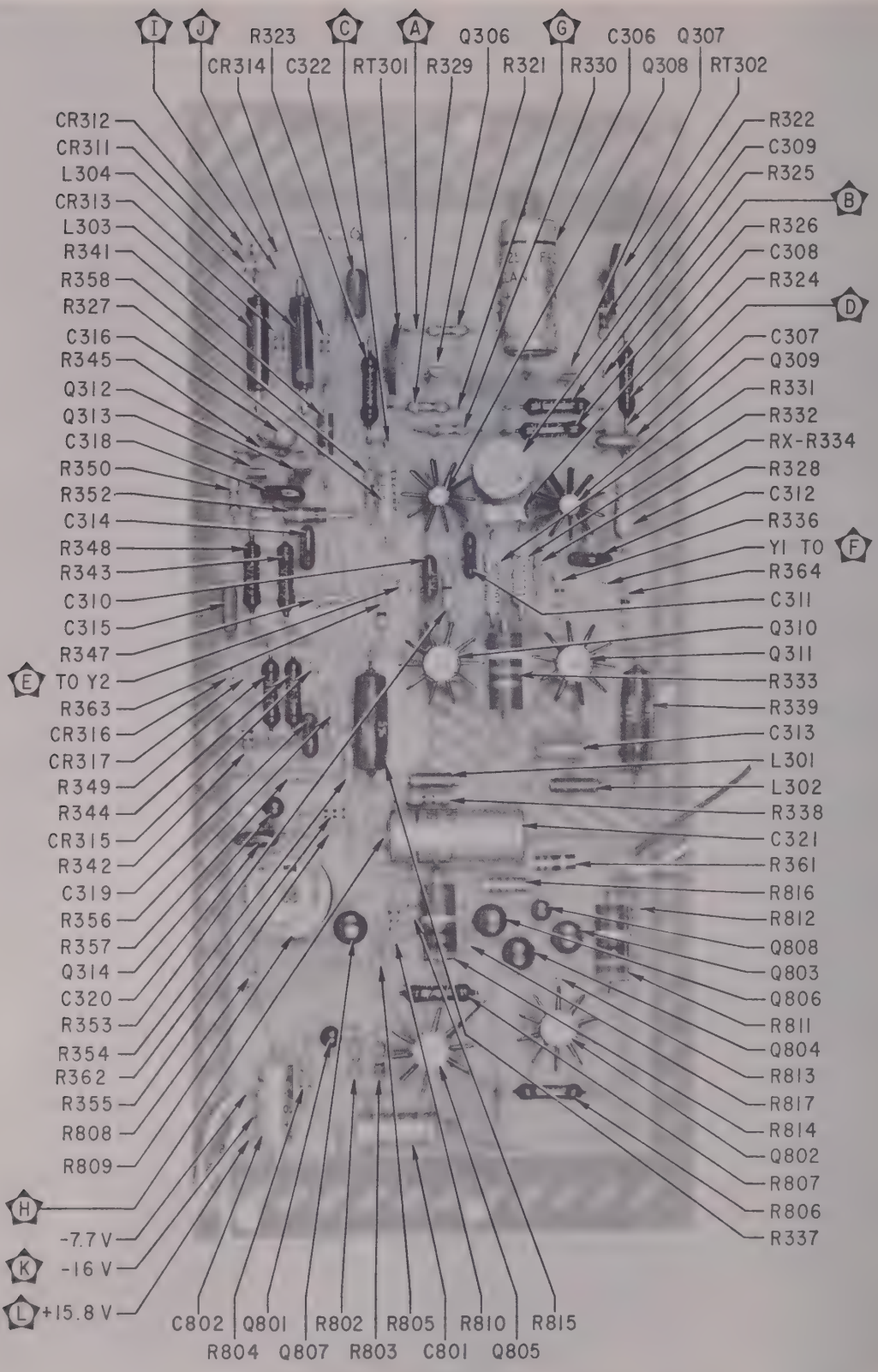


Figure 19. Vertical Amplifier Lower Board

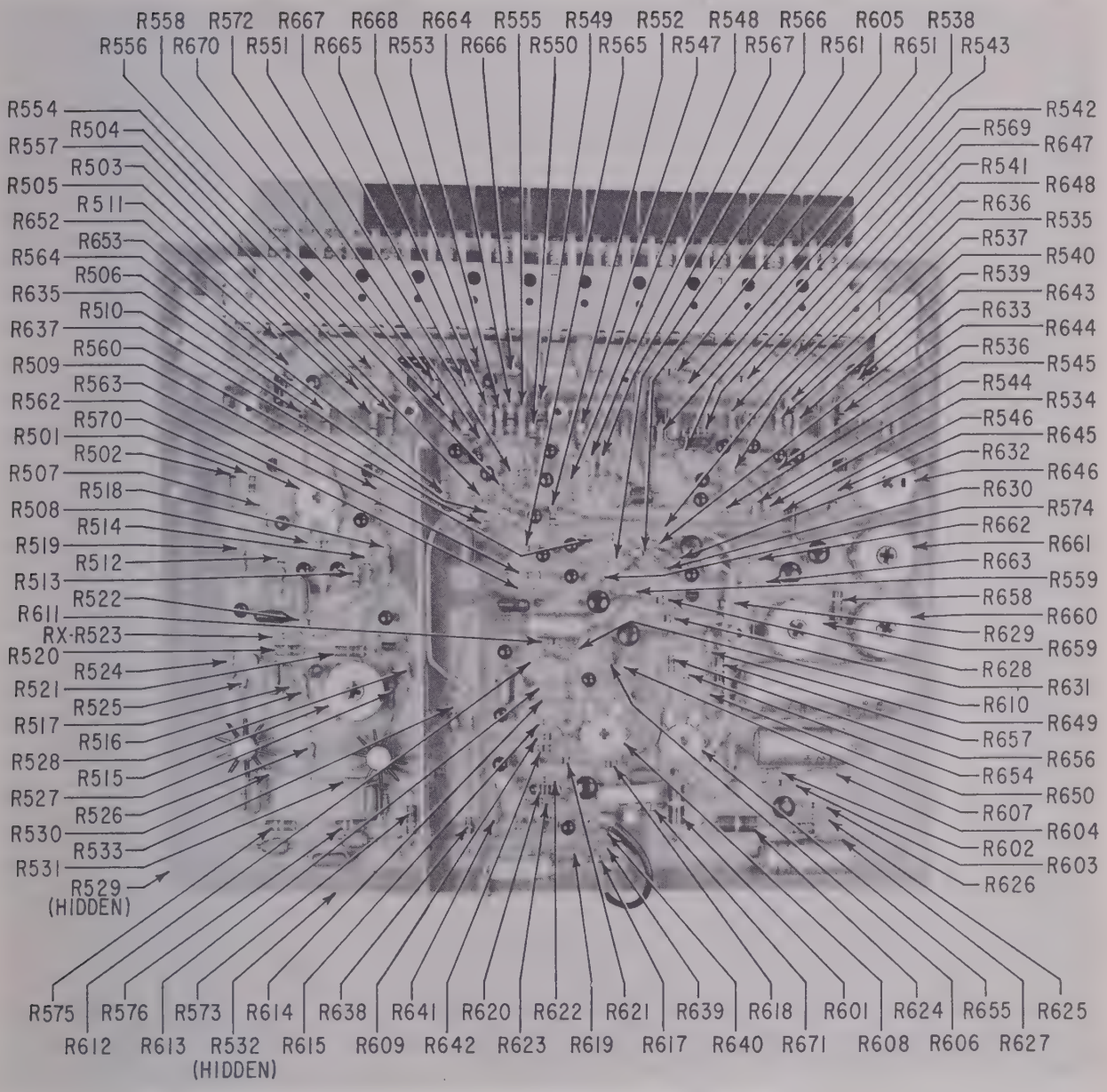


Figure 20. Horizontal Circuitry Board (resistors)

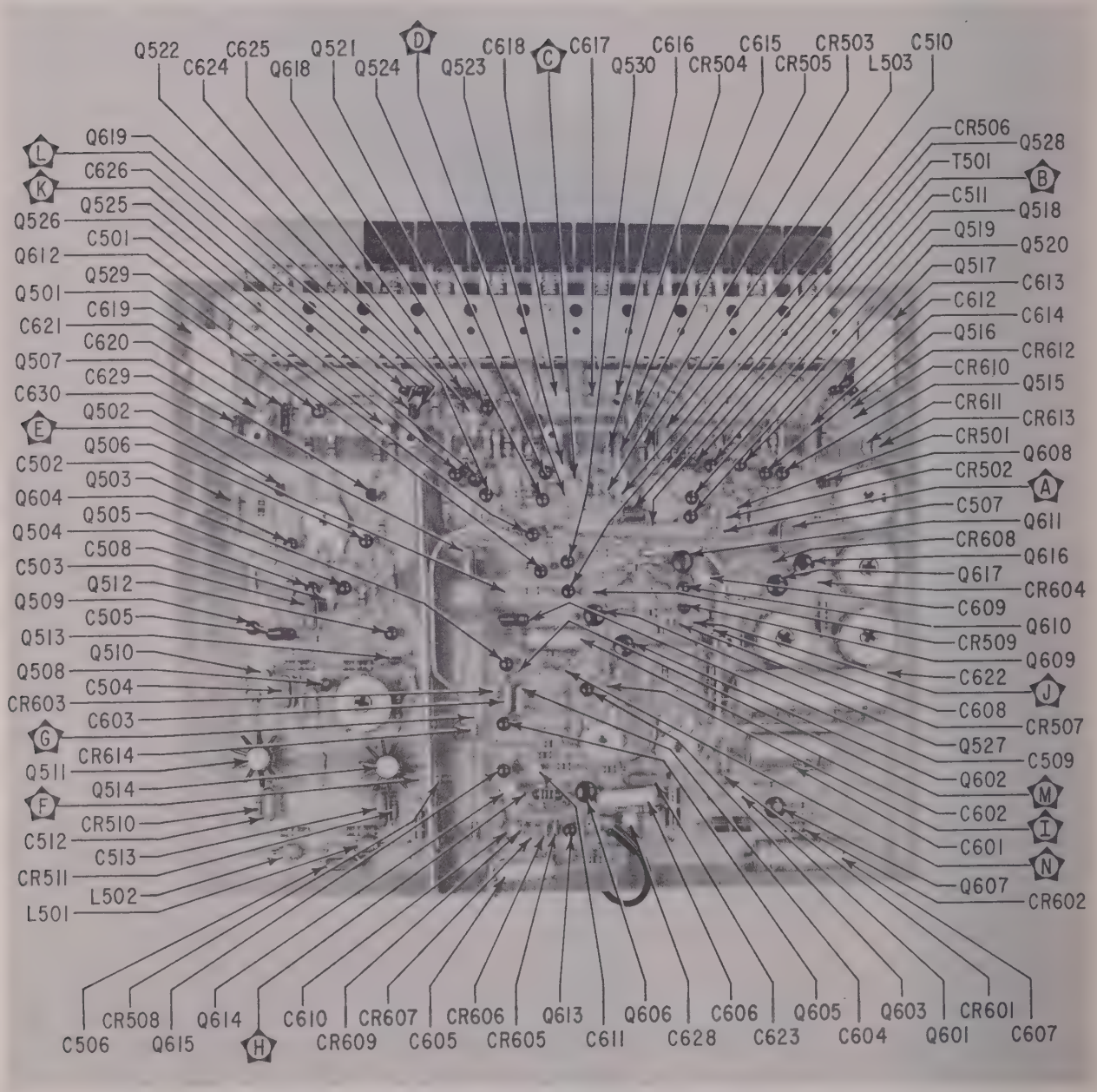


Figure 21. Horizontal Circuitry Board (other components)

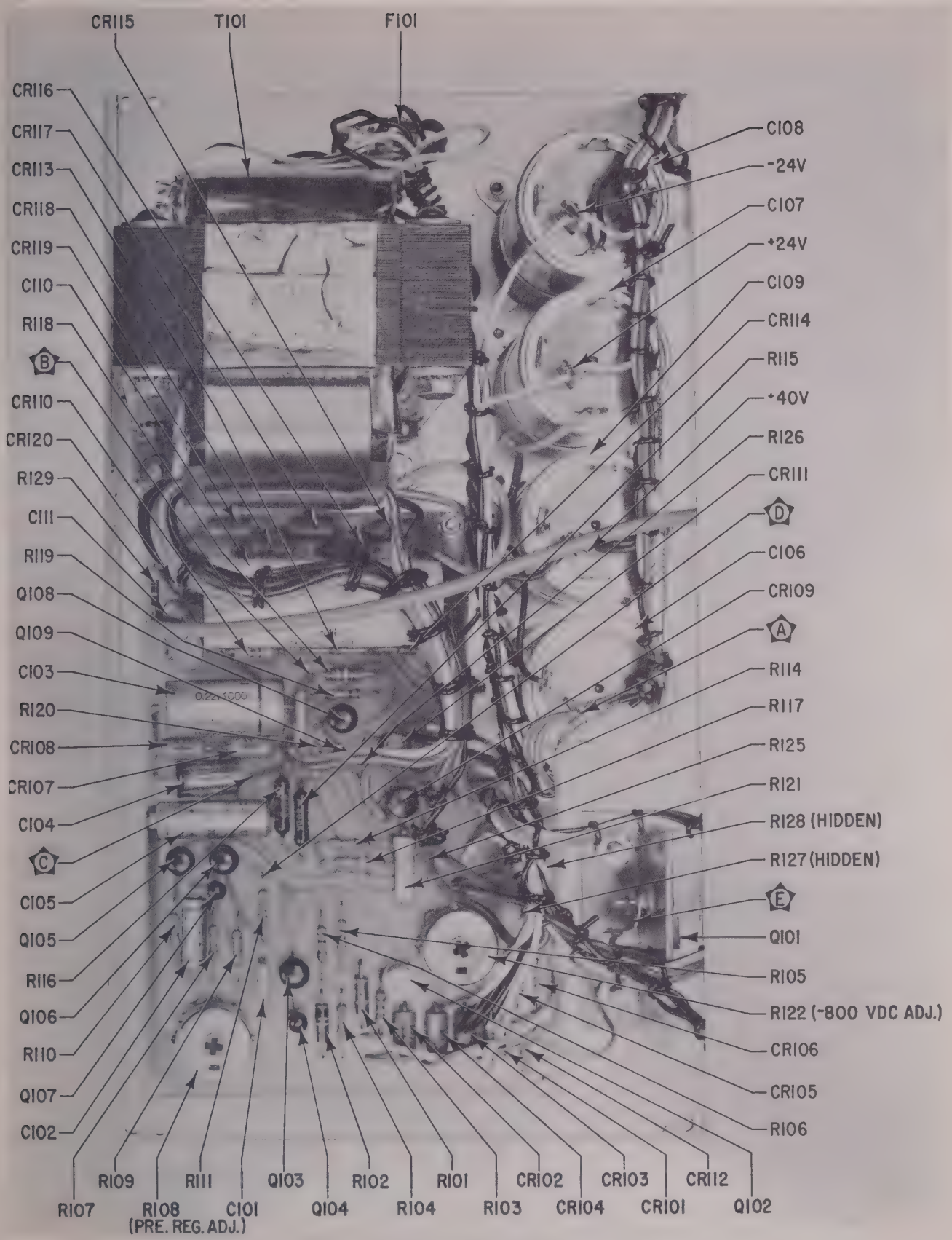


Figure 22. Power Supply

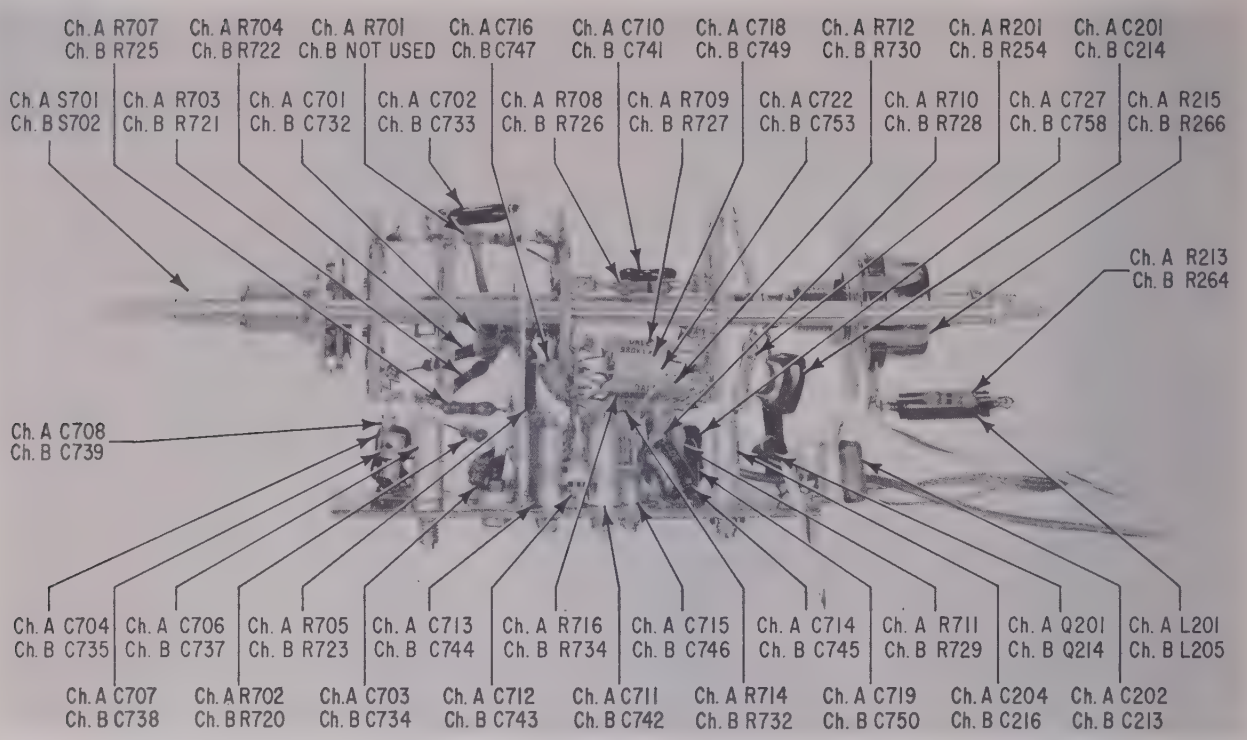


Figure 23. VOLTS/DIVISION Switch, Channels A & B (viewed from top)

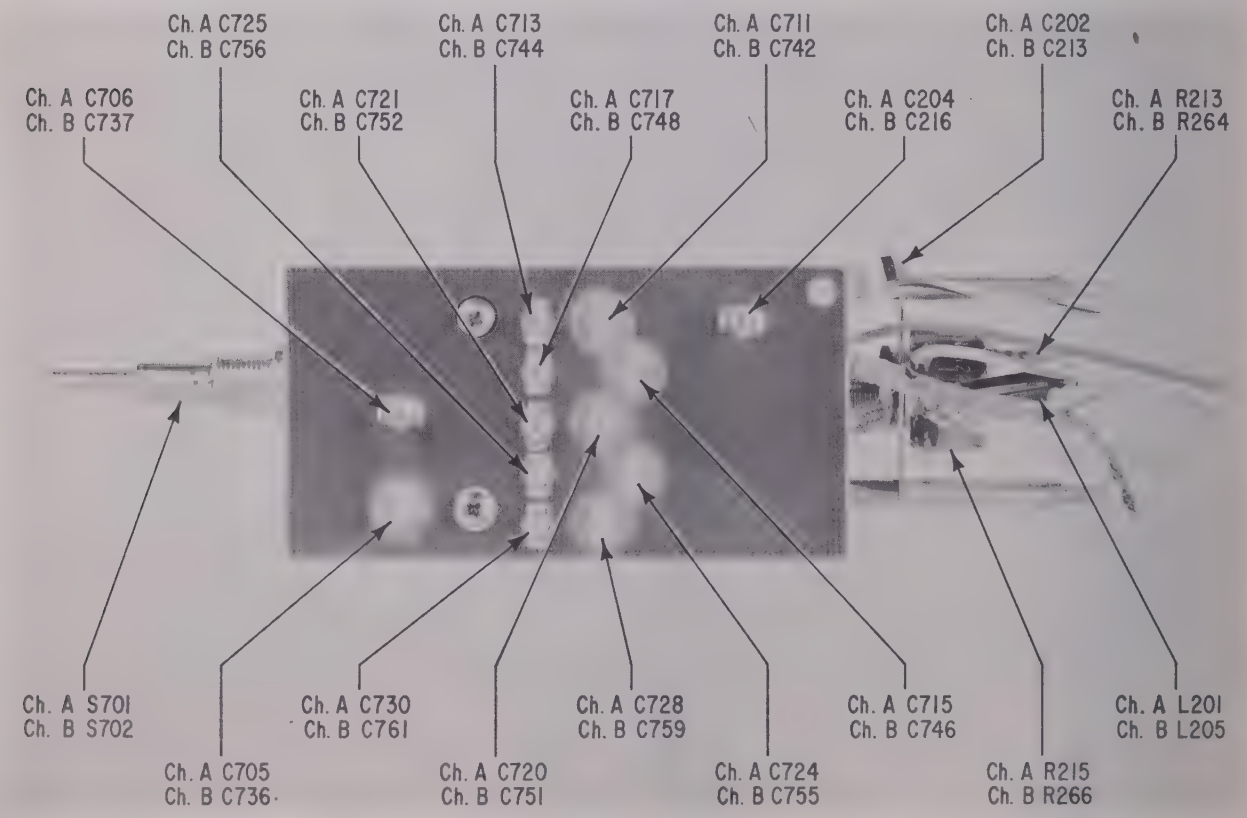


Figure 24. VOLTS/DIVISION Switch, Channels A & B (viewed from side)

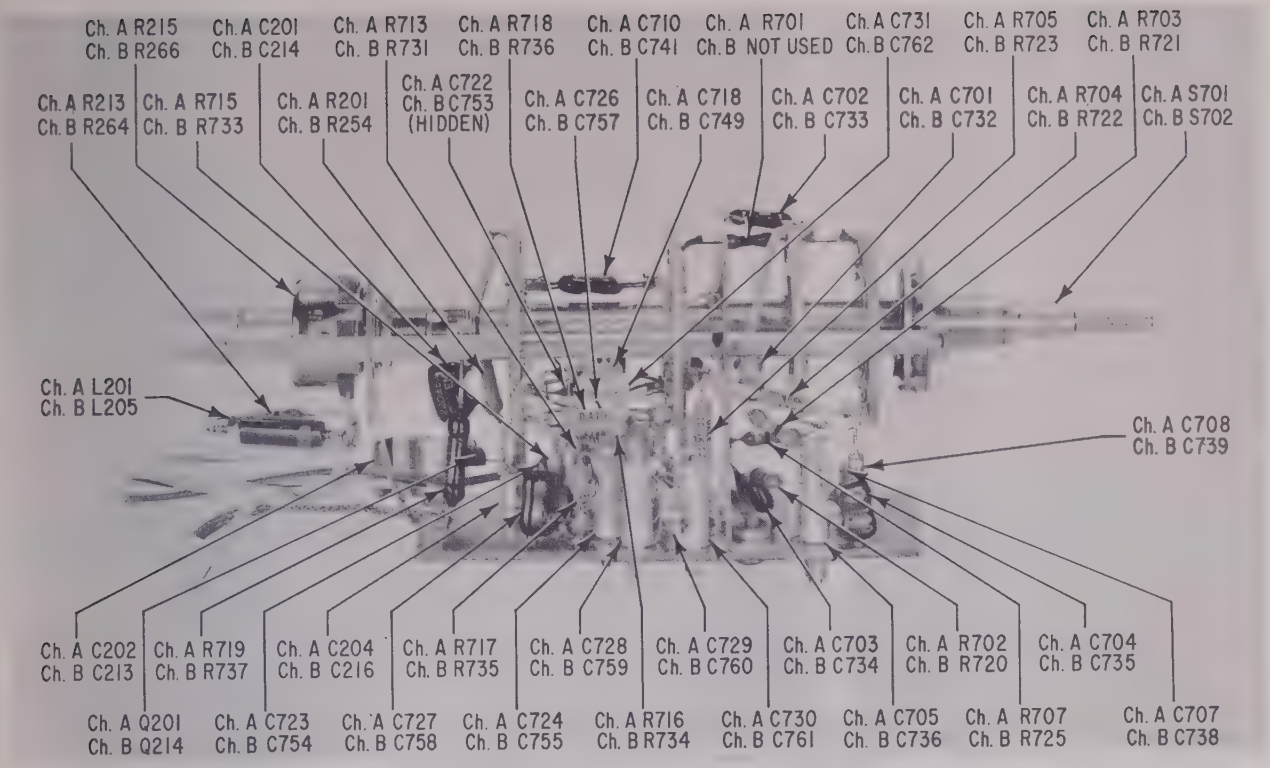


Figure 25. VOLTS/DIVISION Switch, Channels A & B (viewed from bottom)

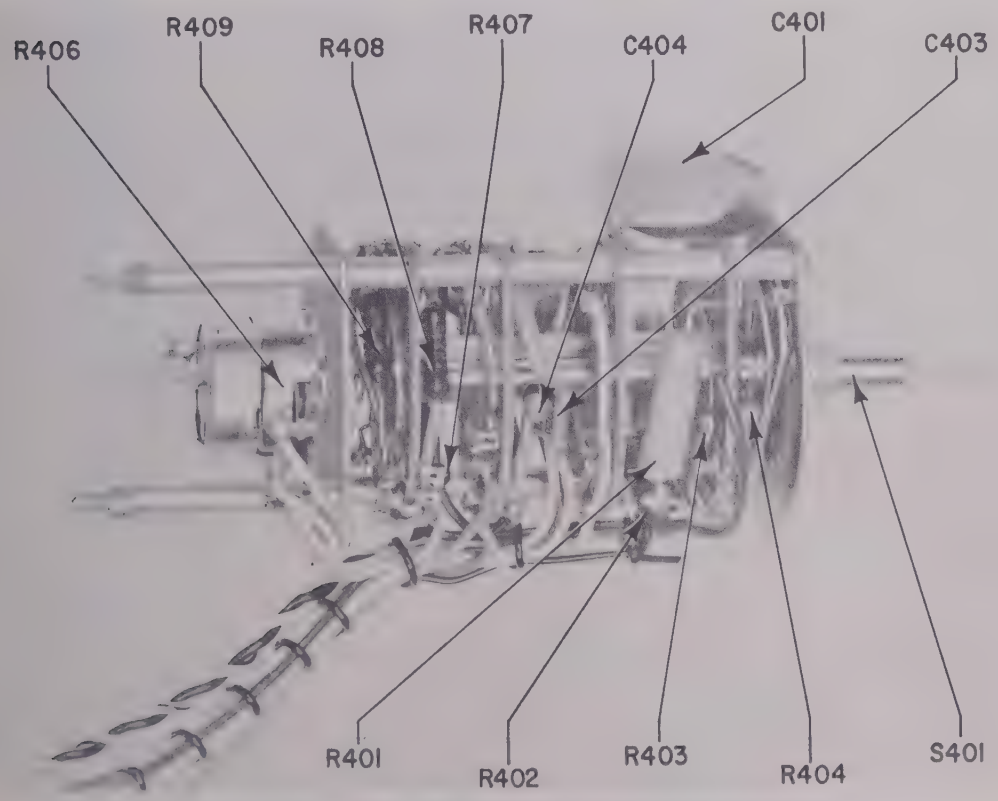


Figure 26. TIME/DIVISION Switch (viewed from top)

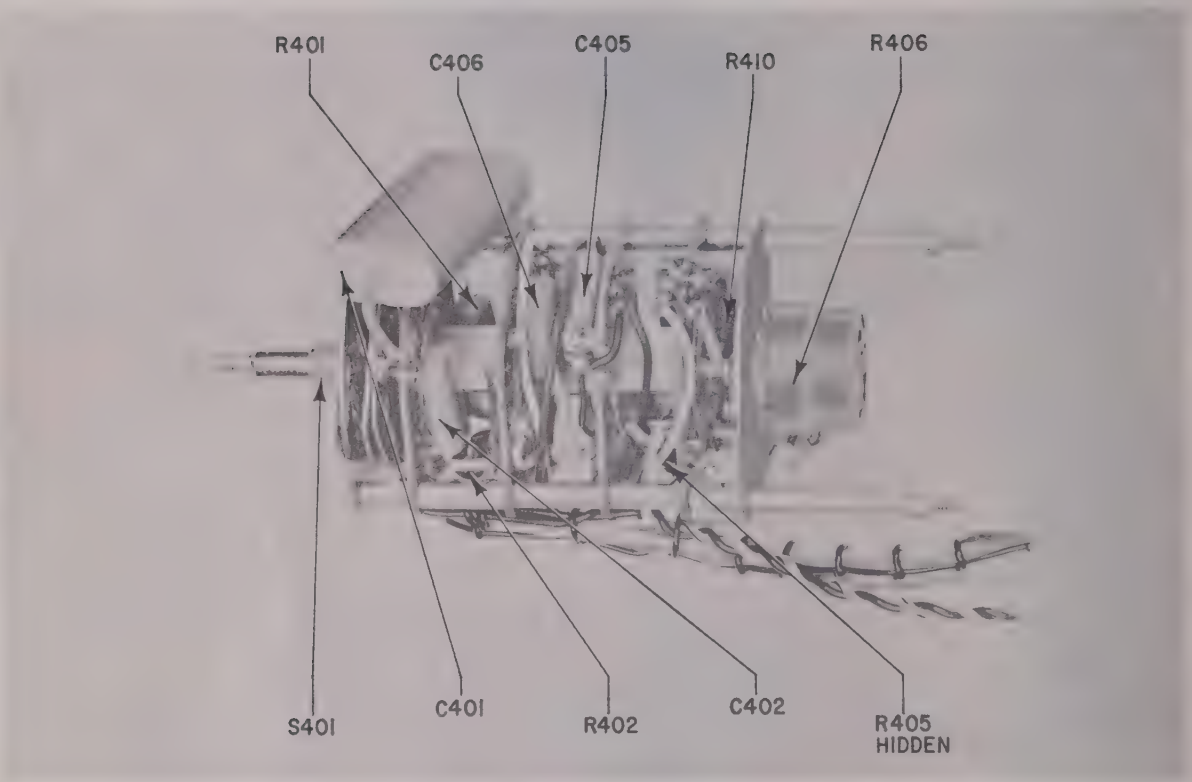


Figure 27. TIME/DIVISION Switch (viewed from bottom)

SECTION VI
CALIBRATION PROCEDURE

The Model 5002 is a stable instrument which will provide many hours of trouble-free operation. However, in order to insure the accuracy of indications, it is suggested that the calibration be checked periodically. This will not only insure the accuracy of measurements but will also serve as a form of preventive maintenance, in that it will help detect developing troubles in the circuitry.

It is also necessary to recalibrate after the replacement of components, in a particular section. If it is necessary to recalibrate the power supplies, the calibration of the unit should then be checked.

Suggested equipment for calibration

DC Voltmeter: DP110 and DMS3200 combination. Require 1% or better accuracy with 100mV full scale capability for DC readings.

Test Scope: 5000 or 5002 recommended. Require calibrated vertical and horizontal deflection.

Time Mark Generator: Hickok Model 1817 or equivalent.

AC Voltmeter: DP130. Requires 1% or better accuracy on a 17.7mV RMS sine wave signal.

Low Frequency Square Wave Generator and Sine Wave Oscillator: Require up to 5V square wave output. Output frequency range 20 Hz to 100 kHz for square wave and up to 1 MHz for sine wave. No overshoot or ringing on square wave; low distortion on sine wave.

Capacity Meter: Tektronix Type 130 L-C meter or equivalent.

High Frequency Square Wave Generator: Tektronix Type 107 or similar type, rise time 5ns or less.

For the following procedures, set the input line to 117V.

Calibration of power supplies

a. Connect the DP110 across the + 135V supply at C106, test point A.

b. Adjust R108 (pre-reg. adj.) for a reading of 135V.

c. Connect the oscilloscope probe to the junction of R118 and R119, test point B.

d. Set the vertical attenuator of the test scope to 50V/DIV and locate the ground base line at the topmost graticule line.

e. Adjust R122 (-800VDC Adj.) so that the ripple wave form observed, with the INTENSITY control in the maximum clockwise position, is centered between ground and the -135V supply without clipping at either top or bottom. Vary line voltage between 105V and 125V and check for clipping on the wave form.

Raster shape adjustments

a. Connect a sine wave oscillator to A INPUT, set mode switch to A, and adjust the amplitude for a six-division deflection and the frequency to approximately 1 MHz.

b. Connect another sine wave oscillator to the HORIZ DISPLAY INPUT and depress the IN ▪ DC button.

(1) Adjust the amplitude of the oscillator for a full scale deflection in the horizontal direction.

(2) Adjust the output frequency for approximately 1 kHz.

c. Adjust R655, (Raster Shape Adj.) for the optimum raster shape, with a minimum of bowing on the extremes of deflection.

Adjustment of calibrator output

a. Connect the voltmeter to the calibrator output jack, CAL .6V P-P.

b. Use a clip lead to form a short circuit between the collector of Q604, test point M, and the junction of R610 and R612, test point N; note the reading of the voltmeter. The approximate reading should be 10mV.

c. Move the jumper from test point N (junction of R610 and R612) to ground.

d. Adjust R608 (CAL Voltage Adj) for a reading of 600mV plus the voltage measured in step b., above.

Horizontal amplifier calibration

Set the front panel controls as follows:

Vertical mode switch	A
A POSITION	Centered
A INPUT	DC
VOLTS/DIV	.5V/DIV
HORIZ DISPLAY	X-AXIS button depressed

a. Rotate the HORIZ POS control to its maximum counterclockwise position. Measure the voltage at the collector of Q511, test point F. Adjust R515 (Current Adj.) until a reading of approximately 2.0 volts is obtained.

b. Apply a 2.5V peak-to-peak 1 kHz square wave to the horizontal input and a 1 kHz sine wave to the A INPUT. Center trace horizontally and vertically. Adjust the sine wave output for full screen deflection.

c. Adjust C620 for minimum overcompensation or undercompensation of the square wave. A properly adjusted square wave will result in two straight lines perpendicular to the horizontal axis.

Calibration of horizontal gain

a. Apply exactly 2.0V peak-to-peak signal to the horizontal input. Deflection should be 10 divisions ±2 minor divisions.

b. If it is necessary to recalibrate the horizontal amplifier, remove R523 from the circuit and connect the decade resistance box from the emitter of Q509 to the emitter of Q512 and set the AC DC GND selector switch to GND.

c. Adjust the resistance box to obtain 10 divisions of deflection ±2 small divisions.

d. Insert the value of resistance determined in step 3 at RX-R523 in the circuit. Recheck horizontal gain by applying a 2.0V peak-to-peak signal and obtaining a 10 division deflection ±2 small divisions.

Adjustment of external trigger source follower

a. Connect the DC voltmeter to the junction of the source of Q608 and R645.

b. Adjust R646 for a reading of zero volts ±10mV.

Adjustment of sweep timing

NOTE: As an aid to calibration, adjust R570 (Bal. Adj.) so that the undeflected spot on the beginning of trace falls exactly on the fifth division with the position control in the extreme clockwise direction. When adjusting the sweep ranges, align the sixth marker on the fifth division before adjusting. When adjusting the sweep it will be noted that the sixth marker will move little from the fifth division and the necessity of readjusting the position control will be greatly reduced.

a. Connect the 1817 Time Mark Generator to A INPUT. Set output for four major divisions. Timing should be measured between first and ninth graticule lines within ±1 minor division. Use the following table to adjust timing:

TABLE V. TIME BASE CALIBRATION

TIME/DIV	Time Mark Generator	Timing Adjustment
50μs	50μs	R660
.1ms	100μs	R660
.2ms	100μs	R660
5μs	5μs	R661
10μs	10μs	R661
20μs	10μs	R661
50ms	50ms	R659
.1 sec	100ms	R659
.2 sec	100ms	R659

Adjustment of horizontal positioning range

a. Depress the X-AXIS button and position the trace to the center of screen.

b. Connect a 1-volt peak-to-peak sine wave to the horizontal input.

c. Adjust the HORIZ POS control to the maximum clockwise extreme and adjust R570 (Bal. Adj.) until only one-half of one division of trace remains on screen on the right-hand side of screen.

Setting of vertical regulated supplies

a. Set HORIZ POS fully clockwise; release X-AXIS button and AUTO button (sweep not running).

b. Adjust R809 for a reading of -16.0 volts at emitter of Q805 (test point K, lower vertical board). Check ripple; it should be less than 5mV peak-to-peak.

c. Measure voltage at emitter of Q802 (test point L); it should be between + 15.5 and + 16.0 volts. Ripple should be less than 5mV peak-to-peak.

d. Measure voltage at emitter of Q801; it should be between -7.5 and -8.0 volts.

Calibration of vertical amplifier

a. Set the controls of the scope under test as follows:

Vertical mode switch	A
VOLTS/DIV (A and B)	10mV
VARIABLE gain (A and B)	Fully clockwise
AC DC GND switch (A AND B)	GND
AUTO button	Depressed
+ button	Depressed
DC button	Depressed
INT button	Depressed
TIME/DIV switch	1MS
HORIZ POS	Full screen trace
ASTIG	Sharp trace
FOCUS	Sharp trace

b. Set A POSITION control to its mechanical center and adjust R208 to center trace on screen. Adjust R222 for + 4.7 volts at collector of Q204 while turning position control to maintain the trace within one division of center. Now turn VARIABLE gain to counterclockwise end and back, observing vertical movement of trace. Adjust R208 for negligible movement as VARIABLE gain is turned. Then reset A POSITION so that trace is centered; loosen knob and set knob with pointer straight up, and tighten. Reset R222 if necessary so collector of Q204 is at + 4.7 volts. Return VARIABLE gain to clockwise end.

c. Set vertical mode switch to B. Set B POSITION control to its mechanical center and adjust R259 to center trace on screen. Adjust R273 for + 4.7 volts at collector of Q217 while turning position control to maintain the trace within one division of center. Now turn VARIABLE gain to counterclockwise end and back, observing vertical movement of trace. Adjust R259 for negligible movement as VARIABLE gain is turned. Then reset B POSITION so that trace is centered; loosen knob and set knob with pointer straight up; tighten. Reset R273 if necessary so collector of Q217 is at 4.7 volts. Return VARIABLE gain to clockwise end.

d. Set vertical mode switch to CHOP. Measure DC voltages at the emitters of Q301 and Q302. They should fall between -4.3 and -4.9 volts.

e. Measure DC voltages at deflection leads. They should fall between + 20 and + 25 volts.

f. Set vertical mode switch to B. Check the voltage across CR311; the voltage should be between+ 0.5 and + 0.8 volts. Check the voltage across CR312; the voltage should be between -11 and -12.5 volts.

g. Set the vertical mode switch to A. Check the voltage across CR311; the voltage should be between -11 and -12.5. Check the voltage across CR312; the voltage should be between + .5 and + .8.

h. Set the vertical mode switch to ALT; set HORIZ POS near counterclockwise end to reduce repetition rate; observe alternate traces, each controlled by its own position knob. Center B trace on screen; rotate A POSITION fully counterclockwise; wait several seconds and rotate A POSITION fully clockwise. B trace should not move more than one-third of a minor division during the next few seconds. Center A trace on screen, rotate B POSITION fully counterclockwise, wait several seconds and rotate B POSITION fully clockwise. The A trace should not move more than one-third of a minor division during the next few seconds.

i. Set the vertical mode switch to CHOP. Observe two traces, each controlled by its own position knob. Clockwise rotation of either A or B POSITION should move the trace upward. Check the voltage across CR311 and CR312; the voltages should be between -5 and -6 volts.

j. Position A and B traces to center of screen. Turn vertical mode switch to A-B. (Trace may move as much as one major division.) Rotate B POSITION clockwise; the trace should move downward.

k. Set the AC DC GND switch of channel B to DC. Set vertical mode switch to B. Apply a 1 kHz sinewave to the B INPUT. Adjust the sinewave amplitude for four major divisions of deflection. Rotate the B POSITION control between its extremes and check to see that the trace goes off screen in both directions. If not, check to see whether there is a 47K, 1/4 watt resistor in parallel with R261 or R262. If such a resistor is found, remove it. Now jumper collectors of Q217 and Q218. If trace moves more than two major divisions, add a 47K, 1/4 watt resistor across R261 (if trace moves up) or R262 (if down). If trace does not move more than two divisions when collectors are shorted and positioning range test above is still not met, look for faulty components in the later stages of the amplifier.

l. Repeat step k for channel A. Refer to Q204 and Q205, R210 and R211.

m. Connect the AC voltmeter to the output of the sine wave oscillator. The oscillator should already be connected to the A INPUT. Adjust the oscillator output until the AC voltmeter reads exactly 17.7mV. Adjust R228 (Gain Adj.) for five divisions of deflection.

n. Repeat step m for channel B, adjusting R279.

Compensation of vertical attenuator

a. Set the front panel controls as follows:

Vertical mode switch	A
A POSITION	Centered
B POSITION	Centered
VARIABLE gain (A and B)	Fully clockwise
AC DC GND (A and B)	DC
VOLTS/DIV (A and B)	10mV/DIV
TIME/DIV	.2 MS
AUTO button	Depressed
+ button	Depressed
AC-HF button	Depressed
INT button	Depressed
HORIZ POS	Full screen deflection

b. Connect the square wave generator to A INPUT. Set frequency to 2.5 kHz. Adjust amplitude for approximately five major divisions of deflection. Position the top of the square wave near the second graticule line. Adjust C204 for a flat top on the square wave, disregarding extreme left corner. (This trimmer has a very slow action.)

c. Set the 107 square wave generator to 1 MHz and connect its output to A INPUT. Adjust amplitude for five major divisions. Set TIME/DIV to .05 μ SEC and adjust HORIZ POS to show leading edge of second or later cycle. Adjust C309 for flat top of square wave with not more than one-fourth minor division overshoot.

d. Set TIME/DIV to .5 μ SEC. Adjust frequency of the 107 square wave generator so the positive half cycle covers about two major horizontal divisions. If the top of the square wave is flat within one-sixth of a minor vertical division, no change is required in R311 or R334. If there is undershoot in the first minor horizontal division, R334 should be lowered; if overshoot, it should be increased. If there is undershoot over one-half of a major horizontal division, R311 should be lowered 20% or more. If there is overshoot, it should be increased. The two compensations interact to some extent on the visual display so that the selection of R334 may have to be repeated.

e. Set the A channel VOLTS/DIV to 20mV. Connect the 130 L-C meter to A INPUT. The capacity measured should be 27 pF ±1 pF. If the capacity is not within the required limits, check lead dress, especially the input lead from the front panel, the lead that connects the 180 pF capacitor and the 250K resistor from the rear of the attenuator switch to the rear compensator, and the wire from the rear compensator to the PC board. If the latter two must be moved away from grounds or other leads, repeat step b.

f. Set the square wave generator to 25 kHz. Connect the square wave output to A INPUT. Set TIME/DIV to 20 μ SEC. Adjust the generator amplitude for approximately five divisions of deflection. Adjust C728 for a flat top on the square wave; if there is any dip or "s effect", set the highest point level with the flat portion of the wave.

g. Set mode switch to B. Repeat steps b, e and f for channel B, adjusting the following capacitors: step b, C216; step f, C759.

h. Set the B VOLTS/DIV on the scope under test to 50mV. The square wave generator should be set at 25 kHz and an amplitude of approximately five divisions. Adjust C755 to obtain a flat top on the square wave. Do the same for the following VOLTS/DIV positions, adjusting indicated capacitors:

VOLTS/DIV	Adjust
.1 volt	C751
.2 volt	C746
.5 volt	C742
1.0 volt	C736

i. Set mode switch to A. Repeat step h for channel A, adjusting indicated capacitors:

VOLTS/DIV	Adjust
50mV	C724
.1 volt	C720
.2 volt	C715
.5 volt	C711
1.0 volt	C705

j. Set the A channel VOLTS/DIV to 10mV. Connect a 10:1 probe to the square wave output and connect the probe output to A INPUT. Set the square wave generator to 2.5 kHz and amplitude for approximately five major divisions of deflection. Set TIME/DIV to .2ms. Adjust the probe for a flat top on the square wave. Leaving the probe undisturbed, set VOLTS/DIV to 20mV. Increase amplitude of square wave generator output for approximately

five major divisions of deflection and adjust C730 for a flat top.

k. Disconnect the probe from A INPUT and connect the L-C meter to A INPUT. Note the reading. Then switch to the 50mV range through 1 volt range, adjusting each indicated capacitor for above reading.

VOLTS/DIV	Adjust
50mV	C725
.1 volt	C721
.2 volt	C717
.5 volt	C713
1.0 volt	C706

l. Set mode switch to B. Set the B channel VOLTS/DIV to 10mV. Connect the 10:1 probe output to B INPUT, set the square wave generator amplitude for approximately five major divisions, and readjust probe for a flat top. Leaving probe undisturbed, set VOLTS/DIV to 20mV, increase amplitude of the square wave generator output for approximately five major divisions of deflection and adjust C761 for a flat top.

m. Repeat step k for the B channel, adjusting the indicated capacitors.

VOLTS/DIV	Adjust
50mV	C756
.1 volt	C752
.2 volt	C748
.5 volt	C744
1.0 volt	C737

n. Set TIME/DIV to .05 μSEC., 107 square wave generator frequency to 1 MHz, vertical mode switch to A and both channels' VOLTS/DIV to 20mV. Connect the 107 output to A INPUT through a 50-ohm termination. Set amplitude for five major divisions of deflection. Using HORIZ POS, observe the leading edge of the second cycle after start of sweep. Switch mode to B, connect signal to B and observe wave form. Touch up C309 if necessary so that, in the channel with greatest peak, the peak does not exceed one-fourth minor division.

SECTION VII PARTS LIST

Reference designations have been assigned to identify all parts used in this instrument. An asterisk designates a part which should be replaced by authorized Hickok repair stations or factories. It is therefore recommended that the entire instrument be returned for repair if trouble exists with such a part.

In ordering parts, refer to the current parts price list for this instrument. Prices are subject to change without notice, and the minimum billing charge is $5.00.

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
C101	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .047 μF, 10% 200 volts	3092-209
C102	CAPACITOR, FIXED, ELECTROLYTIC: 40 μF, 16 volts	3085-345
C103	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .22 μF, 10% 1000 volts	3103-66
C104	CAPACITOR, FIXED, POLYESTER FILM: .01 μF, 10%, 1000 volts	3103-57
C105	CAPACITOR, FIXED, ELECTROLYTIC: 15 μF, 150 volts	3085-354
C106	CAPACITOR, FIXED, ELECTROLYTIC: 200 μF, 150 volts	3085-346
C107	CAPACITOR, FIXED, ELECTROLYTIC: 3000 μF, 25 volts	3085-349
C108	CAPACITOR, FIXED, ELECTROLYTIC: 3000 μF, 25 volts	3085-348
C109	CAPACITOR, FIXED, ELECTROLYTIC: 1200 μF, 50 volts	3085-347
C110	CAPACITOR, FIXED: .1 μF, 20%, 3000 volts	3103-67
C111	CAPACITOR, FIXED, DISC CERAMIC: .005 μF, 3000 volts	3110-281
C201	CAPACITOR, FIXED, DIPPED MICA: 180 pF, 2%, 500 volts	3095-279
C202, C203	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .1 μF, 10%, 200 volts	3092-213
C204	CAPACITOR, VARIABLE: trimmer, .7-3 pF, 350 volts	3115-30
C205	CAPACITOR, FIXED, DIPPED MICA: 10 pF, 10%, 500 volts	3096-505
C206	CAPACITOR, FIXED: calibration, value determined in production	
C207	Same as C202	
C208	CAPACITOR, FIXED, COMPOSITION: 2.2 pF, 10%, 500 volts	3116-7
C209	Same as C206	
C210	Same as C202	
C211	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .01μF, 10%, 200V	3092-201
C212	CAPACITOR, FIXED, DIPPED MICA: 18 pF, 10%, 500 volts	3096-507
C213	Same as C202	
C214	Same as C201	
C215	Same as C202	
C216	Same as C204	
C217	Same as C205	
C218	Same as C206	
C219	Same as C202	
C220	Same as C208	
C221	Same as C206	
C222	Same as C202	
C223, C224	Same as C211	
C225	Same as C202	
C226, C227	Same as C206	
C228	CAPACITOR, FIXED, COMPOSITION: 3.9 pF, 10%, 500 volts	3116-10
C229	Same as C211	
C230	Same as C212	
C231, C232	Same as C206	
C301	CAPACITOR, FIXED, DIPPED MICA: 220 pF, 5%, 500 volts	3096-533
C302	CAPACITOR, FIXED, DIPPED MICA: 22 pF, 10%, 500 volts	3096-509
C303	Same as C208	
C304	CAPACITOR, FIXED, DIPPED MICA: 39 pF, 5%, 500 volts	3096-515
C305	CAPACITOR, FIXED, ELECTROLYTIC: 4.7 μF, 25 volts	3085-343
C306	CAPACITOR, FIXED, ELECTROLYTIC: 250 μF, 25 volts	3085-324
C307	Same as C211	
C308	CAPACITOR, FIXED, CERAMIC: 10 pF ±.25 pF, 500 volts	3110-300
C309	CAPACITOR, VARIABLE: 5-25 pF	3115-80
C310	Same as C205	
C311	CAPACITOR, FIXED, CERAMIC: 18 pF, 5%, 500 volts	3110-301
C312	Same as C205	
C313	Same as C202	
C314	Same as C205	
C315	Same as C211	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
C316	CAPACITOR, FIXED, CERAMIC: 2200 pF, +50 -20%, 500 volts	3111-524
C317	Same as C211	
C318	Same as C205	
C319, C320	CAPACITOR, FIXED, DIPPED MICA: 120 pF, 5%, 500 volts	3096-527
C321	Same as C306	
C322	Same as C202	
C401, C402	CAPACITOR: measured and matched within 2%	3121-32
C403	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .022 μF, 10%, 200 volts	3092-205
C404	CAPACITOR, FIXED, CERAMIC: 1000 pF, +50 -20%, 500 volts	3111-522
C405	CAPACITOR, FIXED, METALLIZED POLYESTER FILM: .47 μF, 10%, 200 volts	3092-221
C501	Same as C305	
C502 thru C504	Same as C202	
C505	Same as C301	
C506, C507	Same as C202	
C508	Same as C316	
C509	Same as C301	
C510	Same as C202	
C511	Same as C301	
C512, C513	Same as C202	
C514	CAPACITOR, FIXED, CERAMIC: 6.8 pF ± .25 pF	3110-304
C601	Same as C306	
C602	CAPACITOR, FIXED, ELECTROLYTIC: 50 μF, 25 volts	3085-300
C603, C604	Same as C403	
C605, C606	Same as C405	
C607	Same as C306	
C608	Same as C403	
C609	CAPACITOR, FIXED, CERAMIC: 4700 pF, +50 -20%, 500 volts	3111-526
C610	Same as C316	
C611	CAPACITOR, FIXED, CERAMIC: 470 pF, 20%, 500 volts	3111-520
C612	CAPACITOR, FIXED, DIPPED MICA: 27 pF, 5%, 500 volts	3096-511
C613	CAPACITOR, FIXED, POLYESTER FILM: .1 μF, 10%, 630 volts	3103-71
C614, C615	Same as C202	
C616, C617	CAPACITOR, FIXED, ELECTROLYTIC: 10 μF, 10 volts	3085-344
C618	Same as C101	
C619	Same as C613	
C620	CAPACITOR, VARIABLE: trimmer, 0.9-9 pF	3115-73
C621	CAPACITOR, FIXED, DIPPED MICA: 56 pF, 5%, 500 volts	3096-519
C622	CAPACITOR, FIXED, ELECTROLYTIC: 100 μF, 150 volts	3085-353
C623	Same as C202	
C624	Same as C316	
C625	Same as C301	
C626	CAPACITOR, FIXED, DIPPED MICA: 330 pF, 5%, 500 volts	3096-537
C627	Same as C206	
C628	Same as C305	
C629	CAPACITOR, FIXED, DIPPED MICA: 15 pF, 10%, 500 volts	3095-267
C630	Same as C202	
C701	Same as C308	
C702	Same as C319	
C703	Same as C304	
C704	CAPACITOR, FIXED, DIPPED MICA: 180 pF, 5%, 500 volts	3096-531
C705, C706	Same as C204	
C707	Same as C308	
C708	CAPACITOR, FIXED, COMPOSITION: .56 pF, 500 volts	3116-14
C709	Same as C613	
C710	Same as C704	
C711	Same as C204	
C712	CAPACITOR, FIXED, CERAMIC: 5.6 pF	3110-141
C713	Same as C204	
C714	CAPACITOR, FIXED, DIPPED MICA: 100 pF, 5%, 500 volts	3096-525
C715	Same as C204	
C716	Same as C228	
C717	Same as C204	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
C718	CAPACITOR, FIXED, CERAMIC: 2.2 pF ±.25 pF	3110-282
C719	CAPACITOR, FIXED, DIPPED MICA: 68 pF, 5%, 500 volts	3096-521
C720, C721	Same as C204	
C722	Same as C514	
C723	Same as C719	
C724, C725	Same as C204	
C726	CAPACITOR, FIXED, CERAMIC: 8.2 pF ±.25 pF, 500 volts	3110-140
C727	CAPACITOR, FIXED, CERAMIC: 27 pF	3110-302
C728	Same as C204	
C729	Same as C208	
C730	Same as C204	
C731, C732	Same as C308	
C733	Same as C319	
C734	Same as C304	
C735	Same as C704	
C736, C737	Same as C204	
C738	Same as C308	
C739	Same as C708	
C740	Same as C613	
C741	Same as C704	
C742	Same as C204	
C743	Same as C712	
C744	Same as C204	
C745	Same as C714	
C746	Same as C204	
C747	Same as C228	
C748	Same as C204	
C749	Same as C718	
C750	Same as C719	
C751, C752	Same as C204	
C753	Same as C514	
C754	Same as C719	
C755, C756	Same as C204	
C757	Same as C726	
C758	Same as C727	
C759	Same as C204	
C760	Same as C208	
C761	Same as C204	
C762	Same as C308	
C763	CAPACITOR, FIXED, COMPOSITION: 1 pF, 10%, 500 volts	3116-11
C801, C802	CAPACITOR, FIXED, ELECTROLYTIC: 10 μF, 25 volts	3085-299
CR101 thru CR104	SEMICONDUCTOR DEVICE: BY127 rectifier	3870-233
CR105, CR106	SEMICONDUCTOR DEVICE, DIODE: 1N914	3870-175
CR107, CR108	Same as CR101	
CR109	SEMICONDUCTOR DEVICE: silicon integrated bridge rectifier VE48	3870-234
CR110	Same as CR101	
CR111	SEMICONDUCTOR DEVICE: diode bridge, W111	3870-227
CR112	SEMICONDUCTOR DEVICE, DIODE: 1N720A	3870-159
CR113, CR114	SEMICONDUCTOR DEVICE, DIODE: 1N2069	3870-62
CR115 thru CR120	Same as CR101	
CR201 thru CR204	Same as CR105	
CR301 thru CR317	Same as CR105	
CR401, CR402	SEMICONDUCTOR DEVICE: 2N5133 used as diode	20861-210
CR501 thru CR507	Same as CR105	
*CR508	SEMICONDUCTOR DEVICE: diode 1N914, selected for 10 μA at 125 volts	3870-265
CR509	Same as CR105	
CR510, CR511	SEMICONDUCTOR DEVICE: diode 1N728A, selected	3870-267
CR601, CR602	SEMICONDUCTOR DEVICE, DIODE: SZ2.4-20	3870-245
CR603, CR604	Same as CR105	
CR605, CR606	Same as CR112	
CR607 thru CR614	Same as CR105	
*DL301	DELAY LINE ASSEMBLY	4115-10
DS101	LAMP: pilot, clear red	12270-60

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
F101	FUSE: 1 amp, tubular	6900-1
J101	CONNECTOR: CRT post accelerator	3475-242
J601	JACK: red nylon body	10300-55
J602, J603	CONNECTOR: receptacle, type UG-657/U	3475-144
J701, J702	Same as J602	
L201	COIL: 4.7 μH	3250-514
L202, L203	COIL: .56 μH	3250-503
L204	COIL: 2.7 μH	3250-511
L205	Same as L201	
L206, L207	COIL: .47 μH	3250-502
L301, L302	COIL: 1.5 μH	3250-508
L303, L304	COIL: 6.8 μH	3250-516
L501, L502	COIL: 15.00 μH	3250-522
L503	COIL: 2.2 μH	3250-510
P101	CORD AND PLUG ASSEMBLY: 3 wire	3675-34
Q101	TRANSISTOR: 2N5297	20861-216
Q102	TRANSISTOR: 2N2102	20861-165
Q103	TRANSISTOR: 2N4889	20861-204
*Q104	SEMICONDUCTOR DEVICE, DIODE: zener	3870-242
Q105, Q106	TRANSISTOR: 2N3566	20861-122
*Q107	Same as Q104	
Q108	Same as Q103	
Q109	TRANSISTOR: 2N5138	20861-221
Q201	SEMICONDUCTOR DEVICE: diode	3870-263
*Q202, Q203	TRANSISTOR, TIS88 selected and paired	20861-250
Q204 thru Q207	TRANSISTOR: 2N4258	20861-197
Q208, Q209	TRANSISTOR: 2N4126	20861-166
Q210, Q211	TRANSISTOR: 2N4124	20861-248
Q212, Q213	Same as Q208	
Q214	Same as Q201	
Q215, Q216	Same as Q202	
Q217 thru Q220	Same as Q204	
Q221, Q222	TRANSISTOR: 2N5139	20861-181
*Q301, Q302	TRANSISTOR: MPS2369	20861-249
Q303	Same as Q221	
Q304	Same as Q204	
Q305	Same as Q210	
Q306, Q307	Same as Q208	
Q308, Q309	TRANSISTOR: 2N2369A	20861-162
Q310, Q311	TRANSISTOR: 2N3866	20861-226
Q312, Q313	Same as Q221	
Q314	Same as Q221	
Q501	Same as Q221	
*Q502	TRANSISTOR: part of matched set 20861-223	20861-223
Q503	TRANSISTOR: 2N5130	20861-171
Q504, Q505	Same as Q104	
Q506	Same as Q503	
*Q507	Same as Q502	
Q508	TRANSISTOR: 2N5306	20861-159
Q509	Same as Q503	
Q510	TRANSISTOR: 2N3906	20861-139
*Q511	TRANSISTOR: 2N2102, selected for breakdown	20861-229
Q512	Same as Q503	
Q513	Same as Q510	
*Q514	Same as Q511	
Q515 thru Q518	Same as Q503	
Q519, Q520	Same as Q204	
Q521, Q522	Same as Q104	
Q523	TRANSISTOR: 2N5179	20861-195
Q524 thru Q526	Same as Q503	
Q527	Same as Q105	
Q528	TRANSISTOR: 2N3640	20861-72
Q529	Same as Q104	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
Q530	Same as Q528	
Q601	TRANSISTOR: 2N5183	20861-227
*Q602	SEMICONDUCTOR DEVICE, DIODE: zener	3870-240
Q603 thru Q605	Same as Q503	
Q606	Same as Q103	
Q607	TRANSISTOR: 2N5040	20861-224
Q608	TRANSISTOR: 2N5458, field effect	20861-132
Q609	TRANSISTOR: 2N4870, unijunction	20861-144
Q610	Same as Q503	
Q611	Same as Q105	
Q612, Q613	TRANSISTOR: 2N5126	20861-213
Q614	TRANSISTOR: 2N5184	20861-200
Q615	Same as Q221	
*Q616	Same as Q602	
Q617	TRANSISTOR: 2N3644	20861-107
Q618	Same as Q612	
*Q619	TRANSISTOR: MPS918, selected	20861-247
Q801	Same as Q221	
Q802	TRANSISTOR: 2N3053	20861-75
Q803	Same as Q617	
Q804	Same as Q105	
Q805	TRANSISTOR: 2N4037	20861-194
Q806	Same as Q105	
Q807	Same as Q617	
Q808	Same as Q104	
R101	RESISTOR, FIXED, COMPOSITION: 1200Ω. 10%, 1/2 watt	18412-122
R102	RESISTOR, FIXED, COMPOSITION: 1.0Ω, 10%, 1/2 watt	18525-815
R103	RESISTOR, FIXED, DEPOSITED CARBON: 100Ω, 5%, 1/4 watt	18470-101
R104, R105	RESISTOR, FIXED, DEPOSITED CARBON: 470Ω, 5%, 1/4 watt	18470-471
R106	RESISTOR, FIXED, DEPOSITED CARBON: 10KΩ, 5%, 1/4 watt	18470-103
R107	RESISTOR, FIXED, DEPOSITED CARBON: 3300Ω, 5%, 1/4 watt	18470-332
R108	RESISTOR, VARIABLE: wire wound, 1000Ω, 20%, 2 watt	16925-576
R109	RESISTOR, FIXED, DEPOSITED CARBON: 1800Ω, 5%, 1/4 watt	18470-182
R110	Same as R104	
R111	RESISTOR, FIXED, DEPOSITED CARBON: 4700Ω, 5%, 1/4 watt	18470-472
R112	RESISTOR, FIXED, DEPOSITED CARBON: 47KΩ, 5%, 1/4 watt	18470-473
R113	RESISTOR, VARIABLE: 100KΩ, 10%, 1/2 watt	40300-104
R114	RESISTOR, FIXED, DEPOSITED CARBON: 2700Ω, 5%, 1/4 watt	18470-272
R115, R116	RESISTOR, FIXED, METAL FILM: 806KΩ, 1%, 1/2 watt	18526-24
R117	Not used	
R118	RESISTOR, FIXED, COMPOSITION: 20 KΩ, 5%, 1/2 watt	18413-201
R119	RESISTOR, FIXED, DEPOSITED CARBON: 1000Ω, 5%, 1/4 watt	18470-102
R120	RESISTOR, FIXED, DEPOSITED CARBON: 180KΩ, 5%, 1/4 watt	18470-184
R121	RESISTOR, FIXED, METAL FILM: 34KΩ, 1%, 1/2 watt	18526-60
R122	RESISTOR, VARIABLE: wire wound, 10KΩ, 20%, 2 watt	16925-569
R123	RESISTOR, VARIABLE: composition, 1MΩ, 20%, 1/2 watt	40300-105
R124	RESISTOR, VARIABLE: composition, 2MΩ, 20%, 1/2 watt	16925-687
R125	Same as R111	
R126	Same as R106	
R127	RESISTOR, FIXED, COMPOSITION: 2.7MΩ, 10%, 1/2 watt	18415-272
R128	RESISTOR, FIXED, COMPOSITION: 4.7MΩ, 10%, 1/2 watt	18415-472
R129	RESISTOR, FIXED, COMPOSITION: 2.2MΩ, 10%, 1/4 watt	18455-222
R201	RESISTOR, FIXED, METAL FILM: 250KΩ, 1%, 1/4 watt	18555-66
R202	RESISTOR, FIXED, DEPOSITED CARBON: 180Ω, 5%, 1/4 watt	18470-181
R203	Same as R119	
R204	RESISTOR, FIXED, CARBON FILM: 5.90MΩ, 2%, 1/4 watt	18555-99
R205	RESISTOR, FIXED, DEPOSITED CARBON: 10Ω, 5%, 1/4 watt	18470-100
R206	RESISTOR, FIXED, COMPOSITION: 7.5MΩ, 5%, 1/2 watt	18415-751
R207	RESISTOR, FIXED, COMPOSITION: 2.2 MΩ, 10%, 1/2 watt	18415-222
R208	RESISTOR, VARIABLE: 10 KΩ, 30%, 1/2 watt	16925-698
R209	RESISTOR, FIXED, COMPOSITION: 1.8MΩ, 5%, 1/4 watt	18455-181
R210, R211	RESISTOR, FIXED, METAL FILM: 1.5KΩ, 1%, 1/2 watt	18526-48
R212	RESISTOR, FIXED, DEPOSITED CARBON: 22KΩ, 5%, 1/4 watt	18470-223

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R213	Same as R114	
R214	RESISTOR, FIXED, DEPOSITED CARBON: 220Ω, 5%, 1/4 watt	18470-221
R215	RESISTOR, VARIABLE: 2.5 KΩ, p/o S701	
R216	RESISTOR, FIXED, METAL FILM: 511Ω, 1%, 1/2 watt	18525-872
R217	RESISTOR, FIXED, DEPOSITED CARBON: 2400Ω, 5%, 1/4 watt	18470-242
R218, R219	RESISTOR, FIXED, DEPOSITED CARBON: 1.3KΩ, 5%, 1/4 watt	18470-132
R220	RESISTOR, FIXED, METAL FILM: 649Ω, 1%, 1/2 watt	18526-57
R221	RESISTOR, FIXED, DEPOSITED CARBON: 3.3Ω, 5%, 1/4 watt	18555-94
R222	RESISTOR, VARIABLE: composition, 500Ω, 20%, 1/4 watt	16925-627
R223	RESISTOR, FIXED, METAL FILM: 200Ω, 1%, 1/2 watt	18526-54
R224	RESISTOR, VARIABLE: 100Ω	16925-683
R225, R226	RESISTOR, FIXED, DEPOSITED CARBON: 75Ω, 5%, 1/4 watt	18470-750
R227	RESISTOR, FIXED, DEPOSITED CARBON: 62Ω, 5%, 1/4 watt	18470-620
R228	RESISTOR, VARIABLE: composition, 200Ω, 20%, 1/2 watt	16925-697
R229, R230	RESISTOR, FIXED, DEPOSITED CARBON: 680Ω, 5%, 1/4 watt	18470-681
R231	RESISTOR, FIXED, DEPOSITED CARBON: 4300Ω, 5%, 1/4 watt	18470-432
R232, R233	RESISTOR, FIXED, DEPOSITED CARBON: 750Ω, 5%, 1/4 watt	18470-751
R234	Same as R231	
R235	Same as R214	
R236, R237	RESISTOR, FIXED, METAL FILM: 4.02KΩ, 1%, 1/2 watt	18526-51
R238	RESISTOR, FIXED, METAL FILM: 2.0KΩ, 1%, 1/2 watt	18526-30
R239	RESISTOR, FIXED, METAL FILM: 1000Ω, 1%, 1/4 watt	18526-19
R240	Same as R238	
R241	Same as R104	
R242, R243	RESISTOR, FIXED, METAL FILM: 12.1KΩ, 1%, 1/2 watt	18525-867
R244, R245	Same as R238	
R246	RESISTOR, FIXED, DEPOSITED CARBON: 47Ω, 5%, 1/4 watt	18470-470
R247, R248	RESISTOR, FIXED, DEPOSITED CARBON: 22Ω, 5%, 1/4 watt	18470-220
R249, R250	Same as R232	
R251, R252	RESISTOR, FIXED, METAL FILM: 249Ω, 1%, 1/2 watt	18526-58
R253	RESISTOR, FIXED, COMPOSITION: 200Ω, 5%, 2 watt	18431-201
R254	Same as R201	
R255	Same as R204	
R256	Same as R205	
R257	Same as R206	
R258	Same as R207	
R259	Same as R208	
R260	Same as R209	
R261, R262	Same as R210	
R263	Same as R212	
R264	Same as R114	
R265	Same as R214	
R266	RESISTOR, VARIABLE: 2.5 KΩ p/o S702	
R267	Same as R216	
R268	Same as R217	
R269, R270	Same as R218	
R271	Same as R220	
R272	Same as R221	
R273	Same as R222	
R274	Same as R223	
R275	Same as R224	
R276, R277	Same as R225	
R278	RESISTOR, FIXED, DEPOSITED CARBON: 82Ω, 5%, 1/4 watt	18470-820
R279	Same as R228	
R280	Same as R278	
R281	Same as R247	
R282	Same as R278	
R283, R284	Same as R231	
R285, R286	RESISTOR, FIXED, DEPOSITED CARBON: 39Ω, 5%, 1/4 watt	18470-390
R287	RESISTOR, FIXED, DEPOSITED CARBON: 1500Ω, 5%, 1/4 watt	18470-152
R288, R289	Same as R251	
R290	Same as R253	
R291	Same as R112	

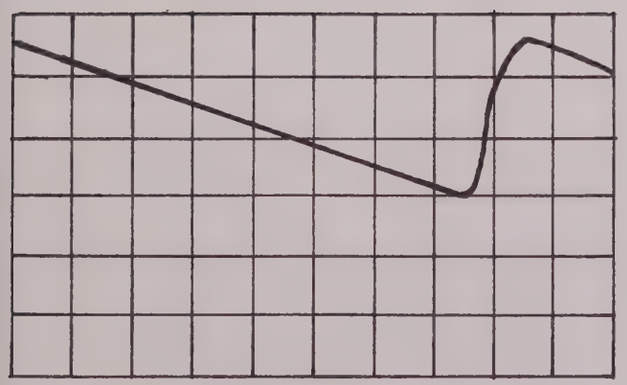
REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R292	Same as R221	
R293, R294	Same as R227	
R301, R302	Same as R287	
R303, R304	RESISTOR, FIXED, DEPOSITED CARBON: 12KΩ, 5%, 1/4 watt	18470-123
R305, R306	RESISTOR, FIXED, METAL FILM: 93.1Ω, 1%, 1/2 watt	18526-53
R307	RESISTOR, FIXED, METAL FILM: 68.1Ω, 1%, 1/2 watt	18525-949
R308	RESISTOR, FIXED, METAL FILM: 590Ω, 1%, 1/2 watt	18526-56
R309	Same as R112	
R310	Same as R212	
R311	RESISTOR, FIXED: calibration, value determined in production	
R312	Same as R307	
R313	Same as R111	
R314	RESISTOR, FIXED, DEPOSITED CARBON: 33KΩ, 5%, 1/4 watt	18470-333
R315	RESISTOR, FIXED, METAL FILM: 3.4KΩ, 1%, 1/2 watt	18526-31
R316	Same as R251	
R317	Same as R218	
R318	RESISTOR, FIXED, DEPOSITED CARBON: 2200Ω, 5%, 1/4 watt	18470-222
R319	RESISTOR, FIXED, DEPOSITED CARBON: 30Ω, 5%, 1/4 watt	18470-300
R320	RESISTOR, FIXED, DEPOSITED CARBON: 240Ω, 5%, 1/4 watt	18470-241
R321, R322	RESISTOR, FIXED, DEPOSITED CARBON: 91Ω, 5%, 1/4 watt	18470-910
R323, R324	Same as R308	
R325, R326	RESISTOR, FIXED, METAL FILM: 2.15KΩ, 1%, 1/2 watt	18526-52
R327, R328	Same as R239	
R329	Same as R246	
R330	Same as R202	
R331, R332	RESISTOR, FIXED, METAL FILM: 100Ω, 1%, 1/2 watt	18525-995
R333	RESISTOR, FIXED, COMPOSITION: 240Ω, 5%, 2 watt	18431-241
R334	Same as R311	
R335, R336	Same as R285	
R337	RESISTOR, FIXED, METAL OXIDE FILM: 680Ω, 5%, 2 watt	18575-561
R338	Same as R205	
R339	Same as R337	
R340	Same as R285	
R341	RESISTOR, FIXED, COMPOSITION: 2000Ω, 5%, 1/2 watt	18412-201
R342	RESISTOR, FIXED, DEPOSITED CARBON: 1100Ω, 5%, 1/4 watt	18470-112
R343	RESISTOR, FIXED, METAL FILM: 2.37KΩ, 1%, 1/2 watt	18526-59
R344	RESISTOR, FIXED, METAL FILM: 1.1KΩ, 1%, 1/2 watt	18526-47
R345	Same as R114	
R346	RESISTOR, FIXED, COMPOSITION: 1100Ω, 5%, 1 watt	18422-111
R347	Same as R112	
R348	Same as R343	
R349	Same as R344	
R350	Same as R114	
R351	Same as R346	
R352	Same as R341	
R353	Same as R285	
R354	RESISTOR, FIXED, DEPOSITED CARBON: 5600Ω, 5%, 1/4 watt	18470-562
R355	RESISTOR, FIXED, DEPOSITED CARBON: 24KΩ, 5%, 1/4 watt	18470-243
R356	Same as R107	
R357	RESISTOR, FIXED, DEPOSITED CARBON: 7500Ω, 5%, 1/4 watt	18470-752
R358	Same as R247	
R359	Same as R112	
R360	Same as R111	
R361	RESISTOR, FIXED, COMPOSITION: 22Ω, 10%, 1/2 watt	18410-222
R362	Same as R205	
R363, R364	Same as R246	
R401	RESISTOR, FIXED, HIGH VOLTAGE OXIDE: 500MΩ, 2%, 1/2 watt	18526-25
R402	RESISTOR, FIXED, METAL FILM: 50MΩ, 1/2%, 1 watt	18550-221
R403	RESISTOR, FIXED, METAL FILM: 5MΩ, 1/2%, 1/4 watt	18555-97
R404	RESISTOR, FIXED, METAL FILM: 500KΩ, 1/2%, 1/4 watt	18555-96
R405	RESISTOR, FIXED, METAL FILM: 83.4KΩ, 1%, 1/2 watt	18526-68
R406	RESISTOR, VARIABLE: 50KΩ, 1/2 watt, part of S401	
R407	RESISTOR, FIXED, METAL FILM: 1.87KΩ, 1/2%, 1/2 watt	18526-67
R408	RESISTOR, FIXED, METAL FILM: 3.4KΩ, 1/2%, 1/2 watt	18526-63

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R409	RESISTOR, FIXED, METAL FILM: 5.76KΩ, 1/2%, 1/2 watt	18526-61
R410	RESISTOR, FIXED, METAL FILM: 14KΩ, 1/2%, 1/2watt	18526-66
R411	RESISTOR, FIXED, METAL FILM: 49.9KΩ, 1%, 1/2 watt	16526-69
R501	Same as R106	
R502	Same as R246	
R503	Same as R247	
R504	RESISTOR, FIXED, COMPOSITION: 750Ω, 5%, 1/2 watt	18411-751
R505	Same as R357	
R506	Same as R103	
R507	Same as R342	
R508	RESISTOR, FIXED, DEPOSITED CARBON: 200Ω, 5%, 1/4 watt	18470-201
R509	Same as R119	
R510	Same as R106	
R511	Same as R103	
R512	Same as R119	
R513	Same as R508	
R514	Same as R119	
R515	RESISTOR, VARIABLE: wire wound, 50Ω, 20%, 2 watt	16925-636
R516	RESISTOR, FIXED, DEPOSITED CARBON: 130Ω, 5%, 1/4 watt	18470-131
R517	Same as R354	
R518, R519	RESISTOR, FIXED, DEPOSITED CARBON: 330Ω, 5%, 1/4 watt	18470-331
R520, R521	RESISTOR, FIXED, COMPOSITION: 82Ω, 10%, 1/2 watt	18410-822
R522	Same as R246	
R523	Same as R311	
R524	Same as R104	
R525	Same as R247	
R526	Same as R354	
R527	Same as R247	
R528	Same as R104	
R529	RESISTOR, FIXED, METAL OXIDE: 2.4KΩ, 2%, 10 watt	18575-540
R530, R531	RESISTOR, FIXED, DEPOSITED CARBON: 75KΩ, 5%, 1/4 watt	18470-753
R532	Same as R529	
R533	Same as R103	
R534	Same as R109	
R535, R536	Same as R214	
R537	Same as R103	
R538	Same as R104	
R539	Same as R354	
R540	Same as R217	
R541	Same as R354	
R542	Same as R104	
R543	RESISTOR, FIXED, DEPOSITED CARBON: 4.7Ω, 5%, 1/4 watt	18555-80
R544	RESISTOR, FIXED, DEPOSITED CARBON: 3900Ω, 5%, 1/4 watt	18470-392
R545	Same as R287	
R546	Same as R544	
R547	RESISTOR, FIXED, DEPOSITED CARBON: 150Ω, 5%, 1/4 watt	18470-151
R548	RESISTOR, FIXED, DEPOSITED CARBON: 1200Ω, 5%, 1/4 watt	18470-122
R549	Same as R341	
R550	Same as R103	
R551	Same as R214	
R552	Same as R119	
R553	Same as R357	
R554	RESISTOR, FIXED, DEPOSITED CARBON: 270Ω, 5%, 1/4 watt	18470-271
R555	Same as R357	
R556	RESISTOR, FIXED, DEPOSITED CARBON: 51Ω, 5%, 1/4 watt	18470-510
R557	Same as R548	
R558	RESISTOR, FIXED, DEPOSITED CARBON: 6800Ω, 5%, 1/4 watt	18470-682
R559	Same as R212	
R560	Same as R109	
R561	Same as R111	
R562	Same as R318	
R563, R564	Same as R547	
R565	Same as R554	
R566, R567	Same as R109	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R568	RESISTOR, VARIABLE: composition, 100 KΩ, 10%, 1/2 watt	16925-686
R569	Same as R106	
R570	RESISTOR, VARIABLE, COMPOSITION: 200Ω, 20%, 1/4 watt	16925-617
R571	Same as R214	
R572	Same as R205	
R573	RESISTOR, FIXED, COMPOSITION: 100Ω, 10%, 1/2 watt	18411-102
R574	Same as R318	
R575, R576	RESISTOR, FIXED, COMPOSITION: 150 KΩ, 10%, 1/2 watt	18414-152
R601	RESISTOR, FIXED, COMPOSITION: 15Ω, 10%, 1 watt	18420-152
R602	Same as R214	
R603	Same as R246	
R604	Same as R212	
R605	Same as R247	
R606	Same as R318	
R607	Same as R217	
R608	RESISTOR, VARIABLE: composition, 1000Ω, 30%, 1/4 watt	16925-600
R609	RESISTOR, FIXED, DEPOSITED CARBON: 300Ω, 5%, 1/4 watt	18470-301
R610	Same as R114	
R611	Same as R119	
R612	Same as R544	
R613	RESISTOR, FIXED, DEPOSITED CARBON: 43 KΩ, 5%, 1/4 watt	18470-433
R614	RESISTOR, FIXED, DEPOSITED CARBON: 39 KΩ, 5%, 1/2 watt	18470-393
R615	Same as R544	
R616	Not used	
R617, R618	Same as R103	
R619	RESISTOR, FIXED, DEPOSITED CARBON: 27 KΩ, 5%, 1/4 watt	18470-273
R620	RESISTOR, FIXED, COMPOSITION: 47 KΩ, 10%, 1/2 watt	18413-472
R621	Same as R119	
R622	Same as R104	
R623	Same as R214	
R624	Same as R601	
R625	Same as R214	
R626	Same as R246	
R627	Same as R212	
R628	Same as R119	
R629	Same as R246	
R630	Same as R129	
R631	RESISTOR, FIXED, DEPOSITED CARBON: 100 KΩ, 5%, 1/4 watt	18470-104
R632	Same as R212	
R633	Same as R354	
R634	Same as R287	
R635	Same as R103	
R636	Same as R111	
R637	Same as R354	
R638	Same as R106	
R639	Same as R544	
R640	Same as R119	
R641	Same as R518	
R642	Same as R119	
R643	Same as R631	
R644	RESISTOR, FIXED, DEPOSITED CARBON: 1MΩ, 5%, 1/4 watt	18470-105
R645	RESISTOR, FIXED, DEPOSITED CARBON: 2000Ω, 5%, 1/4 watt	18470-202
R646	Same as R122	
R647	Same as R246	
R648	Same as R104	
R649	Same as R554	
R650	RESISTOR, FIXED, DEPOSITED CARBON: 15 KΩ, 5%, 1/4 watt	18470-153
R651	Same as R103	
R652	RESISTOR, FIXED, DEPOSITED CARBON: 910 KΩ, 5%, 1/4 watt	18470-914
R653	Same as R631	
R654	RESISTOR, FIXED, DEPOSITED CARBON: 20 KΩ, 5%, 1/4 watt	18470-203
R655	RESISTOR, VARIABLE: composition, 100 KΩ, 20%, 1/4 watt	16925-663
R656	Same as R106	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R657	Same as R573	
R658	Same as R101	
R659 thru R661	RESISTOR, VARIABLE: wire wound, 2 KΩ, 20%, 2 watt	16925-568
R662	RESISTOR, FIXED, DEPOSITED CARBON: 62 KΩ, 5%, 1/4 watt	18470-623
R663	RESISTOR, FIXED, DEPOSITED CARBON: 510Ω, 5%, 1/4 watt	18470-511
R664	Same as R103	
R665	Same as R114	
R666	Same as R354	
R667	Same as R103	
R668	Same as R342	
R669	RESISTOR, VARIABLE: composition, 250Ω, 20%, 1/2 watt, 5-1/2 turns	16925-665
R670	Same as R311	
R671	Same as R103	
R701	Same as R285	
R702	RESISTOR, FIXED, DEPOSITED CARBON: 120Ω, 5%, 1/4 watt	18470-121
R703	Same as R285	
R704	RESISTOR, FIXED, METAL FILM: 990 KΩ, 0.5%, 1/4 watt	18555-74
R705	RESISTOR, FIXED, METAL FILM: 10.1 KΩ, 0.5%, 1/4 watt	18555-73
R706	Same as R227	
R707	Same as R247	
R708	RESISTOR, FIXED, DEPOSITED CARBON: 33Ω, 5%, 1/4 watt	18470-330
R709	RESISTOR, FIXED, METAL FILM: 980 KΩ, 1%, 1/4 watt	18555-71
R710	RESISTOR, FIXED, METAL FILM: 20.5 KΩ, 1%, 1/4 watt	18555-63
R711	RESISTOR, FIXED, METAL FILM: 52.6 KΩ, 1%, 1/4 watt	18555-64
R712	RESISTOR, FIXED, METAL FILM: 950 KΩ, 1%, 1/4 watt	18555-70
R713	RESISTOR, FIXED, METAL FILM: 111 KΩ, 1%, 1/4 watt	18555-65
R714	RESISTOR, FIXED, METAL FILM: 900 KΩ, 1%, 1/4 watt	18555-69
R715	Same as R201	
R716	RESISTOR, FIXED, METAL FILM: 800 KΩ, 1%, 1/4 watt	18555-68
R717	RESISTOR, FIXED, METAL FILM: 1 MΩ, 1%, 1/4 watt	18555-35
R718	RESISTOR, FIXED, METAL FILM: 500 KΩ, 1%, 1/4 watt	18555-67
R719	RESISTOR, FIXED, METAL FILM: 1.2 MΩ, 1%, 1/4 watt	18555-98
R720	Same as R702	
R721	Same as R285	
R722	Same as R704	
R723	Same as R705	
R724	Same as R227	
R725	Same as R247	
R726	Same as R708	
R727	Same as R709	
R728	Same as R710	
R729	Same as R711	
R730	Same as R712	
R731	Same as R713	
R732	Same as R714	
R733	Same as R201	
R734	Same as R716	
R735	Same as R717	
R736	Same as R718	
R737	Same as R719	
R801	RESISTOR, FIXED, COMPOSITION: 270Ω, 10%, 1/2 watt	18411-272
R802	Same as R218	
R803	Same as R645	
R804	Same as R109	
R805	Same as R318	
R806	RESISTOR, FIXED, METAL FILM: 3.16 KΩ, 1%, 1/2 watt	18525-923
R807	Same as R315	
R808	Same as R109	
R809	RESISTOR, VARIABLE: wire wound, 500Ω, 20%, 2 watt	16925-654
R810	Same as R342	
R811	RESISTOR, FIXED, COMPOSITION: 18Ω, 10%, 2 watt	18430-182
R812	Same as R548	
R813	Same as R318	

REF. DESIG.	DESCRIPTION	HICKOK PART NO.
R814	RESISTOR, FIXED, COMPOSITION: 10Ω, 10%, 2 watt	18430-102
R815	RESISTOR, FIXED, DEPOSITED CARBON: 390Ω, 5%, 1/2 watt	18470-391
R816	RESISTOR, FIXED, COMPOSITION: 470Ω, 10%, 1/2 watt	18411-472
R817	Same as R318	
*RT301, RT302	THERMISTOR	18682-48
S101	SWITCH: slide, dpdt	19911-109
*S201	SWITCH: rotary, mode	19912-652
*S401	SWITCH: rotary, sweep, supplied with a 50KΩ, 1/2 watt variable resistor mounted on rear	19912-642
S402	SWITCH SPDT: p/o R406	
*S601 thru S611	SWITCH: push button, 11 station	19910-204
*S701, S702	SWITCH: rotary, vertical attenuator	19912-653
S703, S704	SWITCH: slide, single pole, 3 positions, 5 amp @ 125 volts	19911-108
*T101	TRANSFORMER: power	20800-372
*T501	TRANSFORMER	20800-363
*V101	TUBE ASSEMBLY: cathode ray, potted	20877-37
XF101	HOLDER: fuse, screw slot cap	8825-200
	BOOKLET: instructions	2490-612

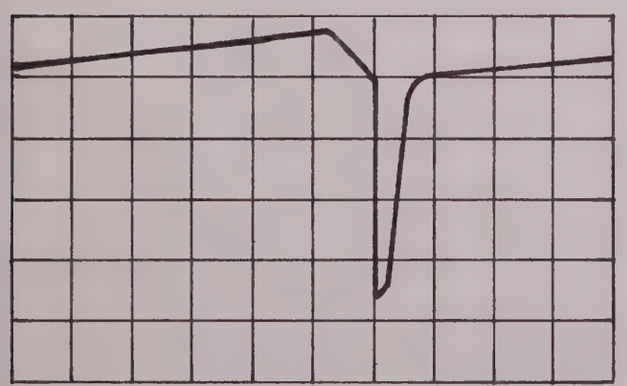


2 m sec/div.

TEST POINT B

20v/div.

(junction of R119 and R118)

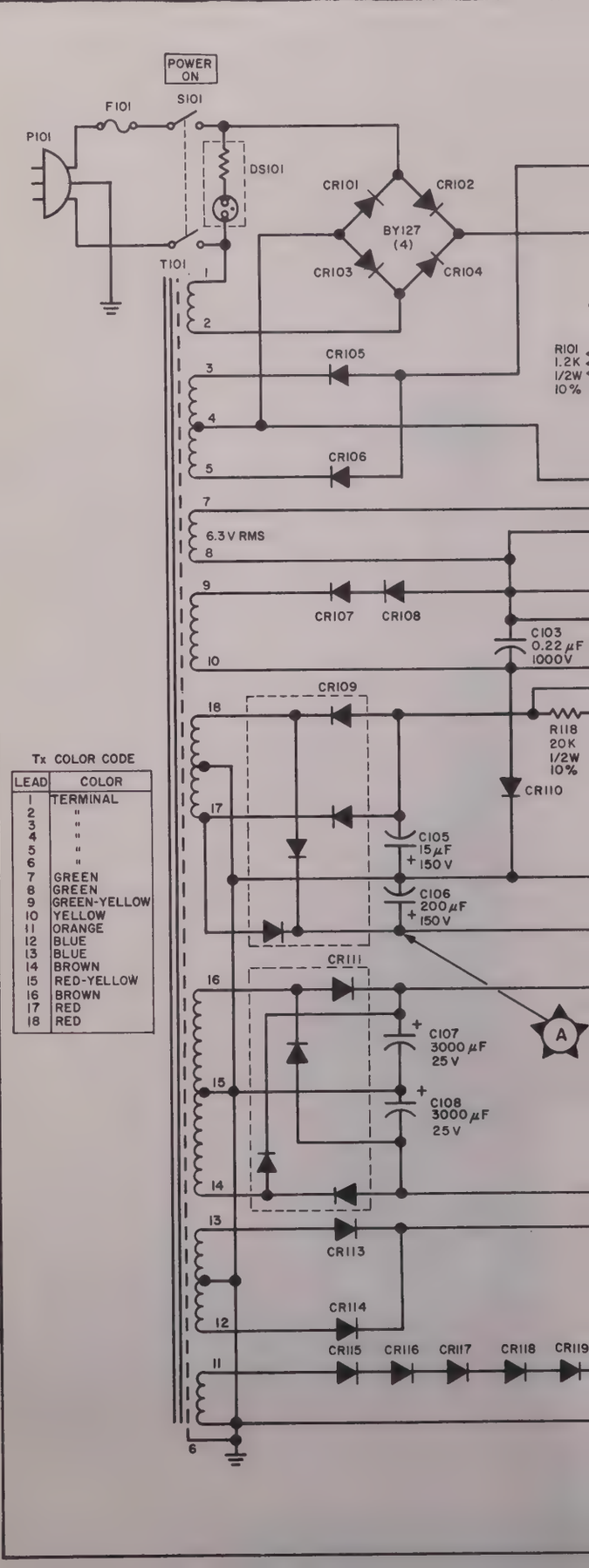


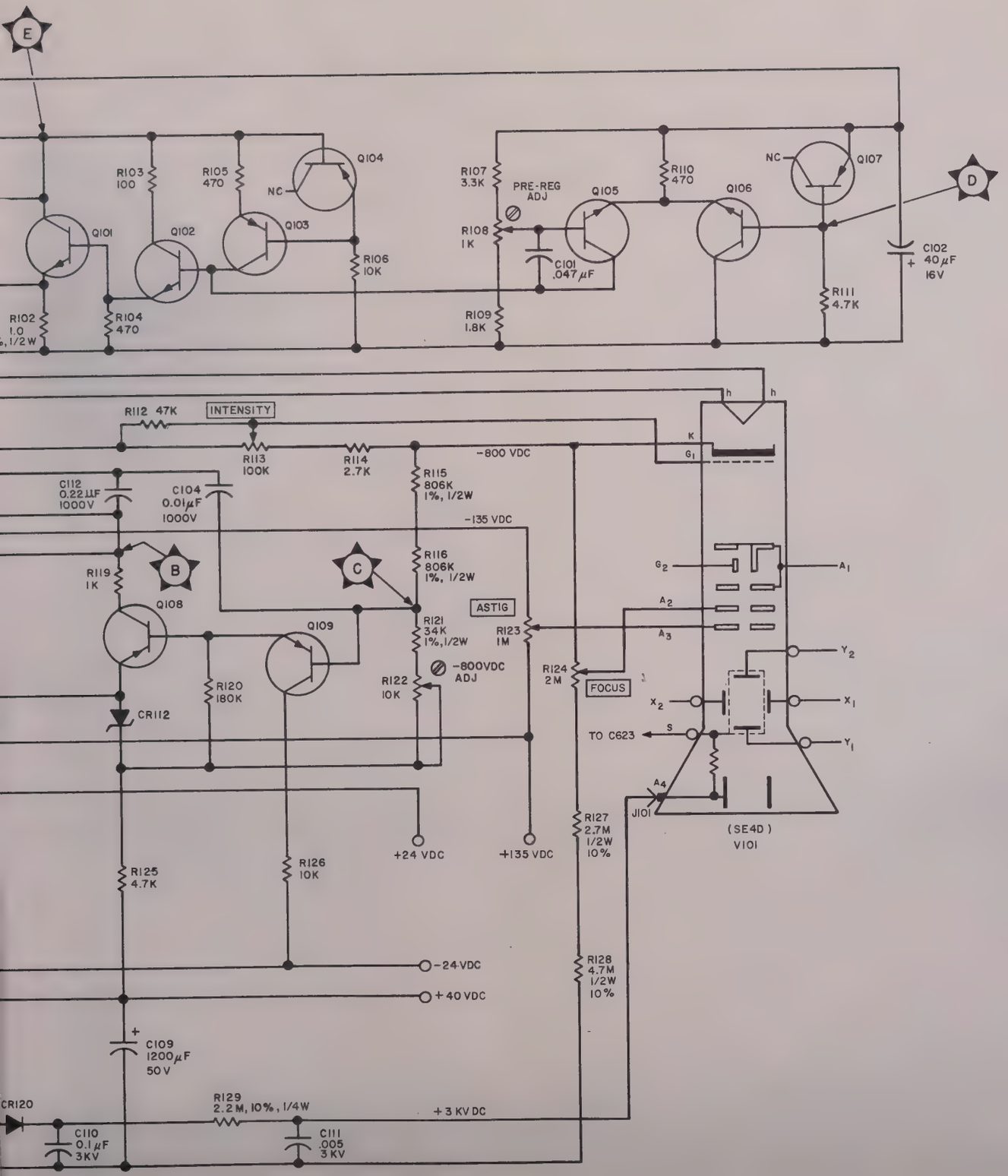
2 m sec/div.

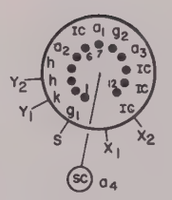
TEST POINT C

.05/div.

(junction of R116, R121 and base of Q109)







NOTES:

UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/4 W, 5%
VALUES IN OHMS
K = 1000
M = 1,000,000

CAPACITANCES ARE IN MICROFARADS.

CONNECTION

NO CONNECTION

DENOTES FRONT PANEL MARKING.

INTERNAL SCREWDRIVER ADJUST.

SYMBOLS	
LAST USED	NOT USED
C112	R117
CR120	
F101	
J101	
DS101	
Q109	
R129	
S101	
V101	

FIG. 28 — SCHEMATIC WIRING DIAGRAM MODEL 5002 POWER SUPPLY Sheet 1 of 8

ALT.	DRAWING NUMBER
	902-495W

TO R719

R201 250K 1/4W 1%
C201 180
R204 5.9M 1/2W 2%
C204 .7-3
C206 CX
C231 CX
R209 1.8M
Q201
CR205
NC
C202 .1μF
R202 180
C203 .1μF
R205 10
R206 7.5M 1/2W 5%
R207 2.2M 1/2W 10%
R208 10K DC BAL A
R210 1.5K 1/2W 1%
R211 1.5K 1/2W 1%
R212 22K
R213 2.7K
C207 .1μF
R214 220
L201 4.7
R215 2.5K VARIABLE CAL
R216 511 1/2W 1%
C208 2.2
R217 2.4K
R218 1.3K
CR201
Q202
Q203
Q204
C209 CX
R219 1.3K
R220 649 1/2W 1%
Q205
R221 3.3
C226 CX
DC LEVEL ADJ
R222 500
R223 200 1/2W 1%
C210 .1μF
R224 100
R225 75
R226 75
A POSITION
GAIN ADJ
R228 250
R227 82
Q206
Q207
C217 10
R293 62
C205 10
R229 680
S201 A ALT CHOP A-B B
S201C FRONT
C212 18
R241 470
Q208
Q209
R230 680
R231 4.3K
R233 750
C230 18
R232 750
R235 220
R294 62
R234 4.3K
C211 .01μF
R238 2K 1/2W 1%
Q210
Q211
R236 4020 1/2W 1%
R237 4020 1/2W 1%
R239 1K 1/2W 1%
R240 2K 1/2W 1%
R242 12.1K 1/2W 1%
R243 12.1K 1/2W 1%
R244 2K 1/2W, 1%
R245 2K 1/2W 1%
R246 47
Q212
Q213
R247 22
R248 22
R249 750
R250 750
S201B FRONT
S201C FRONT
S201C REAR
R251 249 1/2W 1%
L202 .56
L203 .56
L204 2.7
CR202
R252 249 1/2W 1%
R253 200 2W 5%
TO CR301
TO S603
TO CR302
TO R320
TO R304
TO CR306
TO CR307
C229 .01μF
R292 3.3
C225 .1μF
S201B REAR
R290 200 2W 5%
R291 47K
CR204
L206 .47
L207 .47
R287 1.5K
R288 249 1/2W 1%
R289 249 1/2W 1%
S201A FRONT
S201A REAR
S201B FRONT
S201B REAR
R280 82
Q221
R285 39
R283 4.3K
R281 22
C223 .01μF
C224 .01μF
R284 4.3K
Q222
R282 82
R286 39
C228 3.9
R203 1K
C214 180
R254 250K 1/4W 1%
C216 .7-3
R255 5.9M 1/2W 2%
C218 CX
C232 CX
R260 1.8M
Q214
CR206
C213 .1μF
C215 .1μF
R256 10
R257 7.5M 1/2W 5%
R258 2.2M 1/2W 10%
R259 10K DC BAL B
R261 1.5K 1/2W, 1%
R262 1.5K 1/2W 1%
R263 22K
C219 .1μF
R264 2.7K
L205 4.7
R265 220
R266 2.5K VARIABLE CAL
R267 511 1/2W 1%
C220 2.2
R268 2.4K
R269 1.3K
CR203
Q215
Q216
Q217
C221 CX
R270 1.3K
R271 649 1/2W, 1%
Q218
R272 3.3
C222 .1μF
DC LEVEL ADJ
R273 500
R274 200 1/2W 1%
C227 CX
R275 100
R276 75
B POSITION
GAIN ADJ
R279 250
R278 82
R277 75
Q219
Q220
TO R737
+15.8 VDC
-16 VDC
-7.7 VDC

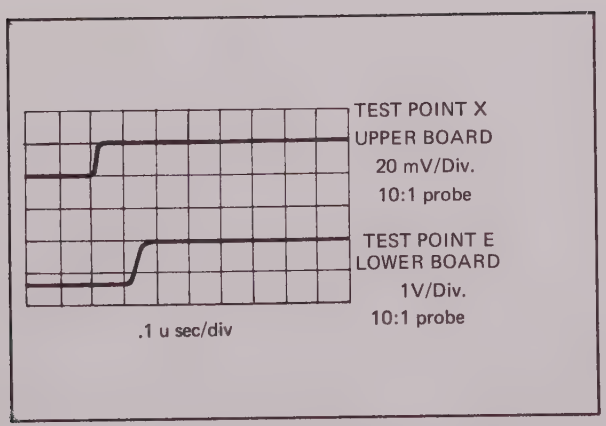
RX, CX DENOTE CALIBRATION VALUES DETERMINED IN PRODUCTION

NOTES:
UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/4W, 5%
VALUES IN OHMS, K=1,000 M=1,000,000
CAPACITANCES ARE IN PICOFARADS.

CONNECTION
NO CONNECTION
DENOTES FRONT PANEL MARKING.
INTERNAL SCREWDRIVER ADJUST.

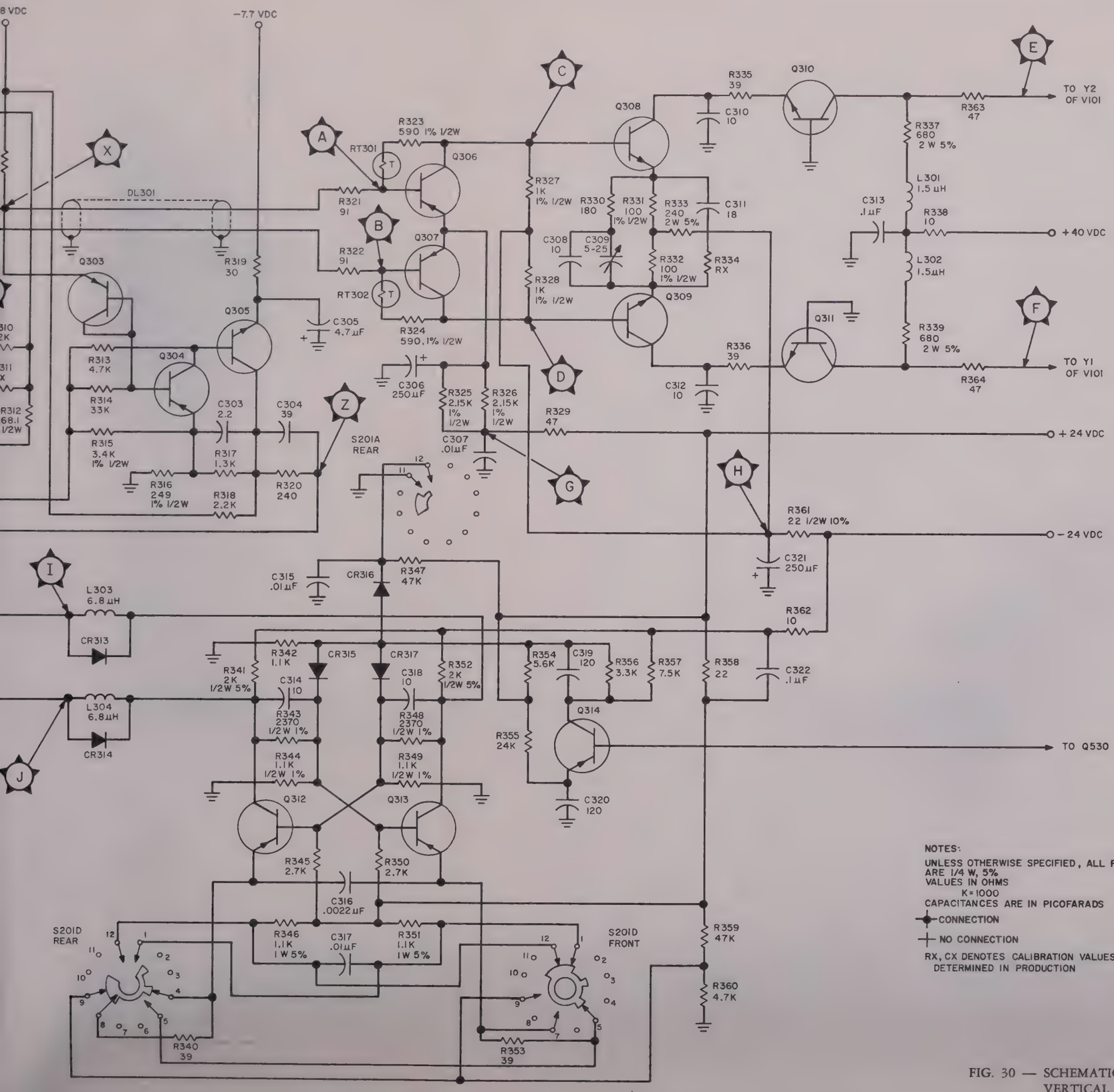
SYMBOLS	
LAST USED	NOT USED
C232	
CR206	
L207	
Q222	
R294	
S201	

FIG. 29 — SCHEMATIC WIRING DIAGRAM MODEL 5002 VERTICAL AMPLIFIER Sheet 2 of 8



Wave Forms, Vertical Delay
Line Test Points

ALT.	DRAWING NUMBER
	902-495W



NOTES:

UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/4 W, 5%
VALUES IN OHMS
K = 1000
CAPACITANCES ARE IN PICOFARADS

CONNECTION

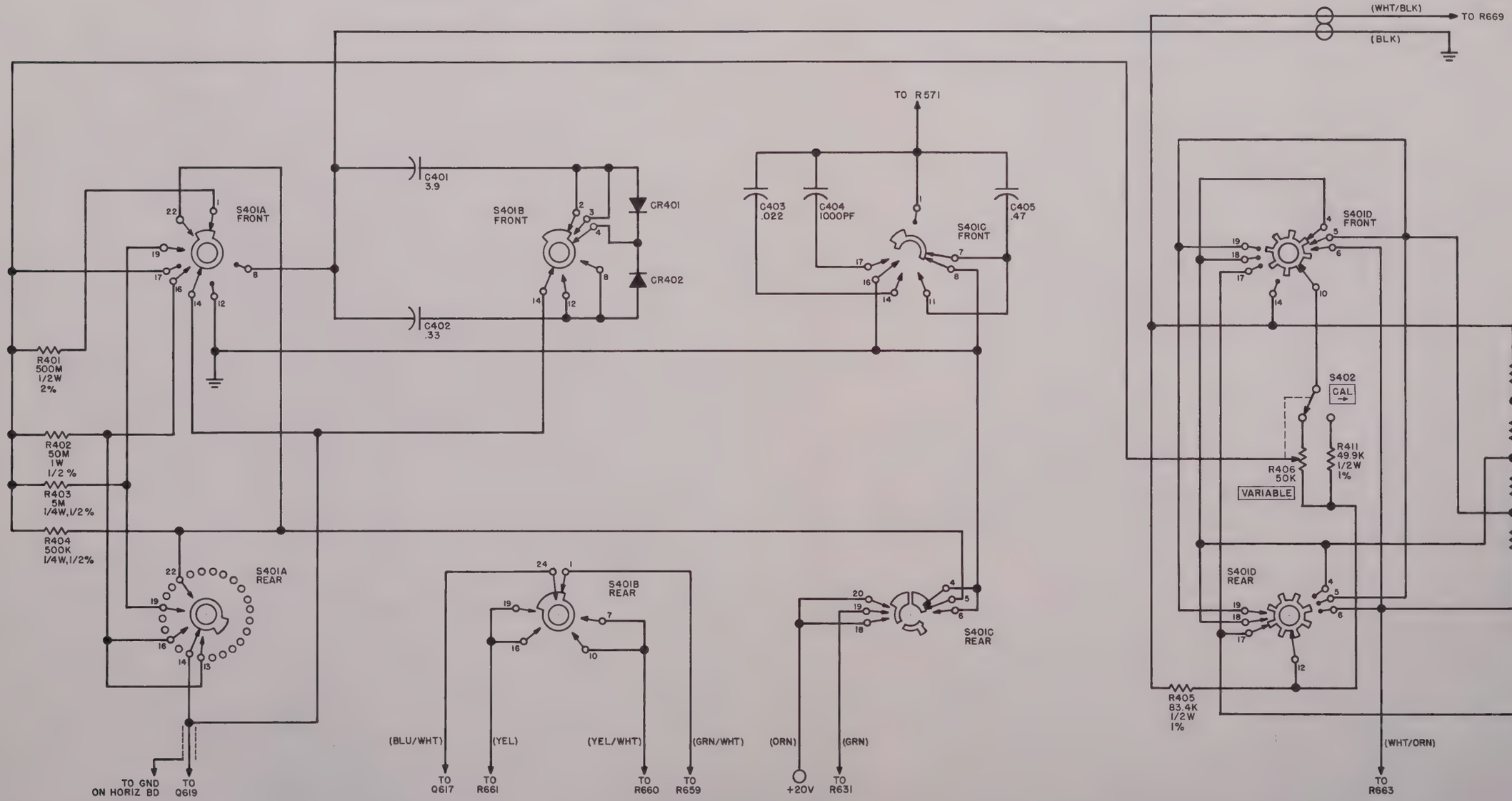
NO CONNECTION

RX, CX DENOTES CALIBRATION VALUES DETERMINED IN PRODUCTION

SYMBOLS	
LAST USED	NOT USED
C322	
CR317	
Q314	
R364	
RT302	
DL301	
S201	

FIG. 30 — SCHEMATIC WIRING DIAGRAM MODEL 5002 VERTICAL AMPLIFIER Sheet 3 of 8

ALTERATION	DRAWING NUMBER
	902-495 W



SYMBOLS	
LAST USED	NOT USED
C405 R411 CR402 S402	

NOTES:

UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/4W, 1%
VALUES IN OHMS
K = 1000
M = 1,000,000

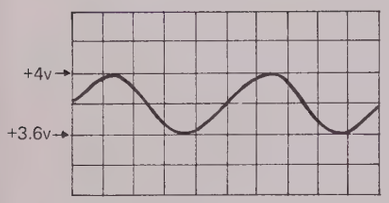
CAPACITANCES ARE IN MICROFARADS.
PF = PICOFARADS.

= CONNECTION

= NO CONNECTION

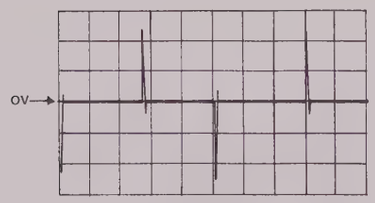
DENOTES FRONT PANEL MARKING.

FIG. 31 — SCHEMATIC WIRING DIAGRAM MODEL 5002
TIME/DIVISION SWITCH Sheet 4 of 8



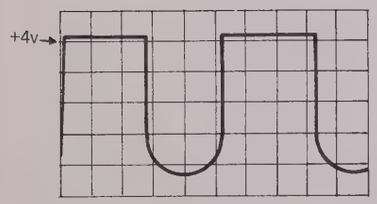
TEST POINT A
TRIGGER LEVEL
MAXIMUM CCW

.2v/div
2 μ sec/div



TEST POINT C
(Slope -)

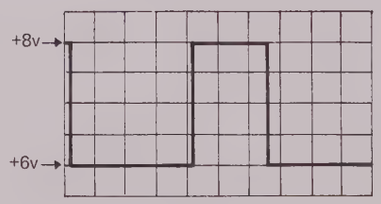
.1v/div
2 μ sec/div



TEST POINT A
TRIGGER LEVEL

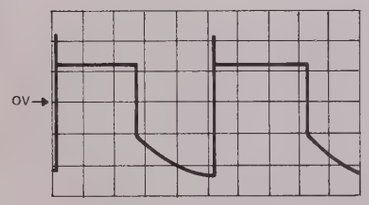
.2v/div
2 μ sec/div

(adjusted for steady
scope presentation)



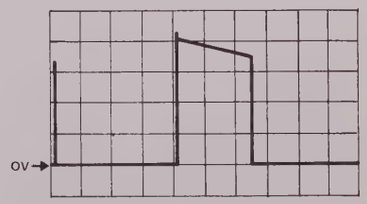
TEST POINT D

.5v/div
20 μ sec/div



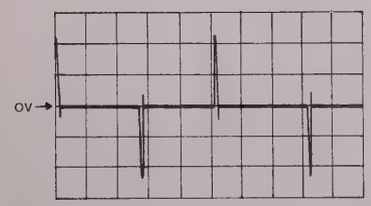
TEST POINT B

.2v/div
2 μ sec/div



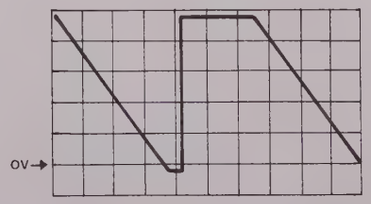
TEST POINT E

.2v/div
20 μ sec/div



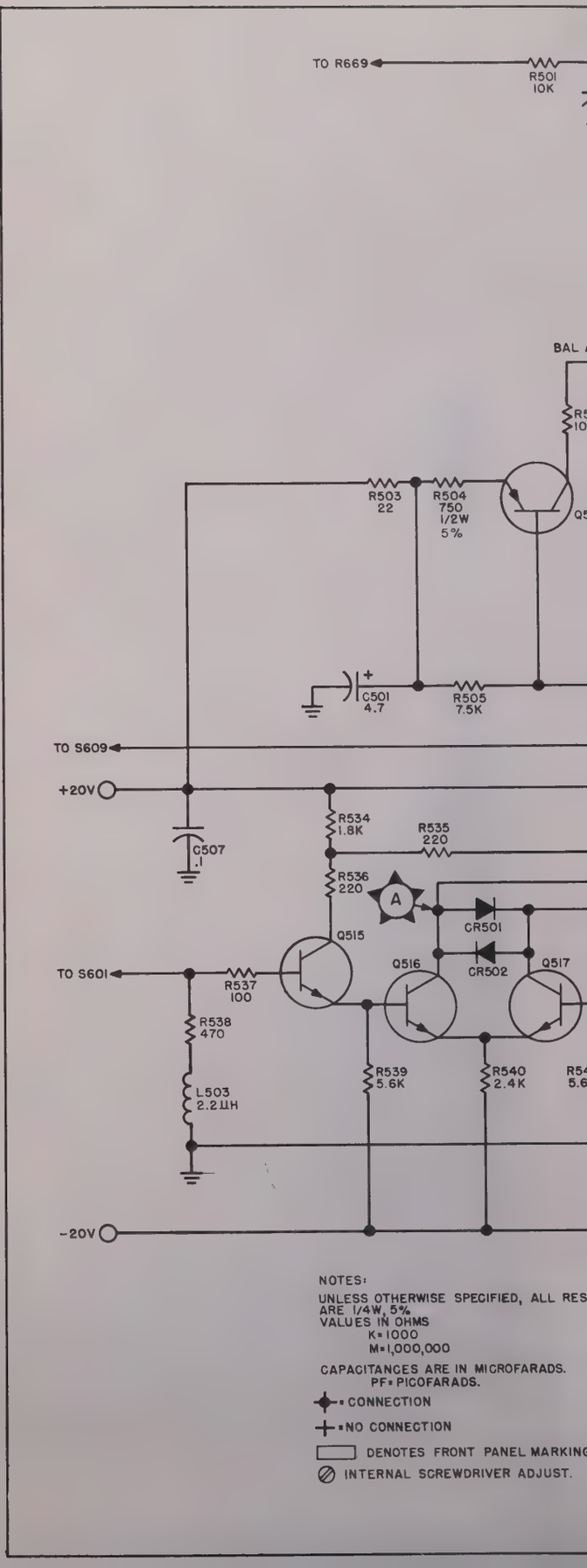
TEST POINT C
(Slope +)

.1v/div
2 μ sec/div



TEST POINT F

20v/div
20 μ sec/div



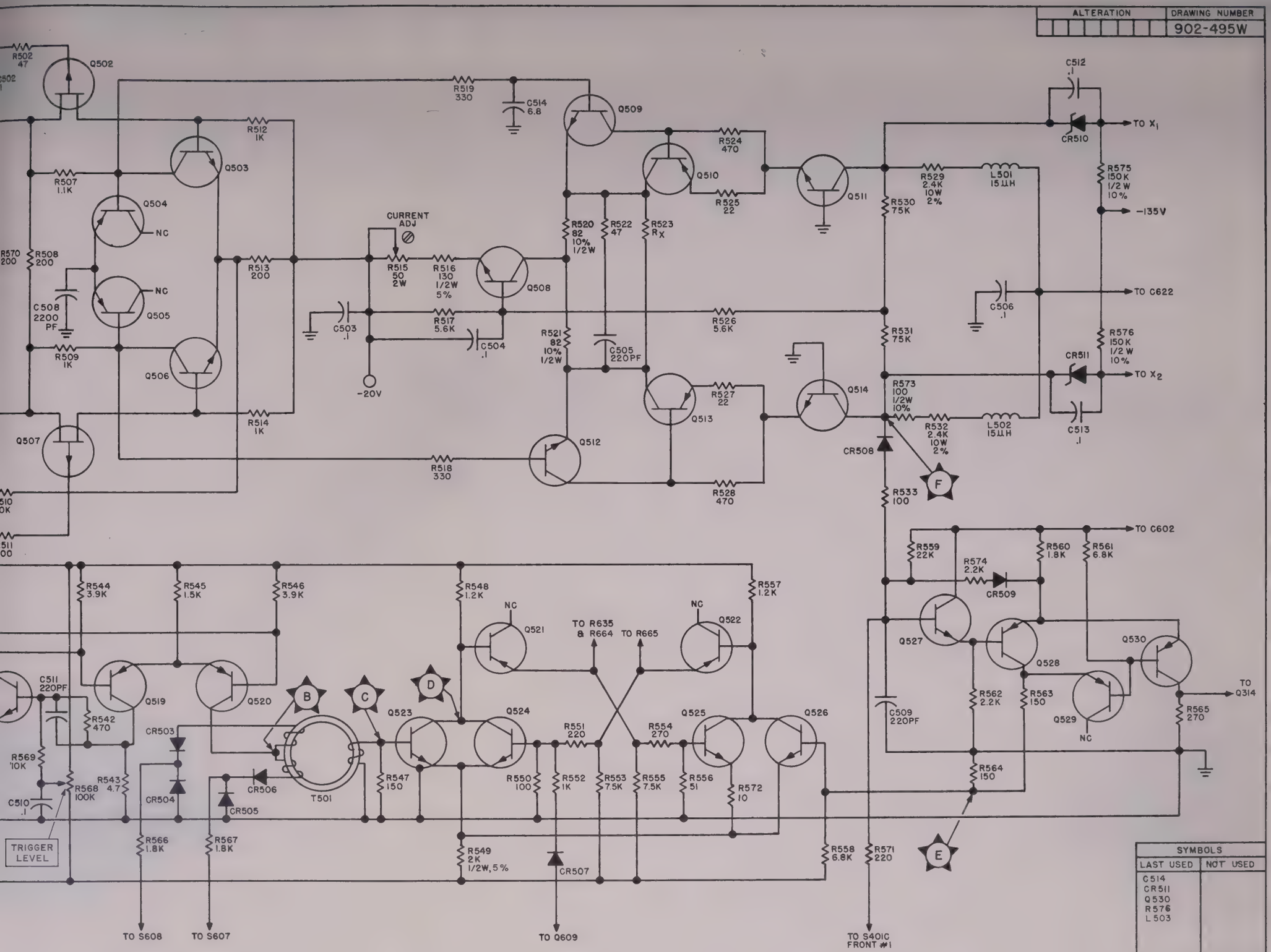
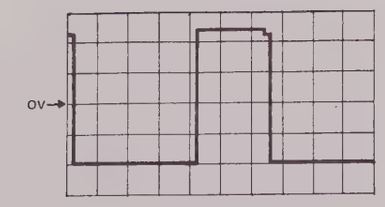
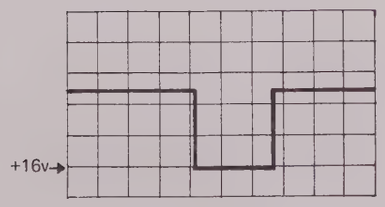


FIG. 32 — SCHEMATIC WIRING DIAGRAM MODEL 5002
HORIZONTAL BOARD A Sheet 5 of 8



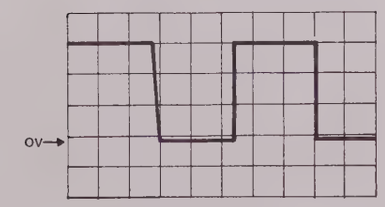
TEST POINT G

.5v/div
20μ sec/div



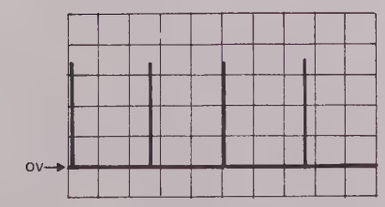
TEST POINT H

20v/div
20μ sec/div



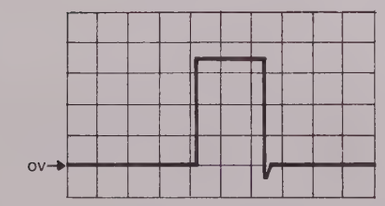
TEST POINT I

2v/div
.2 m sec/div



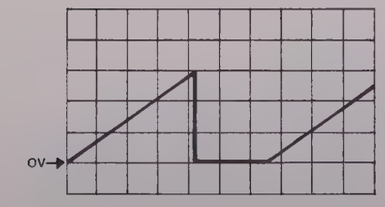
TEST POINT J
TRIGGER LEVEL
MAXIMUM CCW

2v/div
1 m sec/div



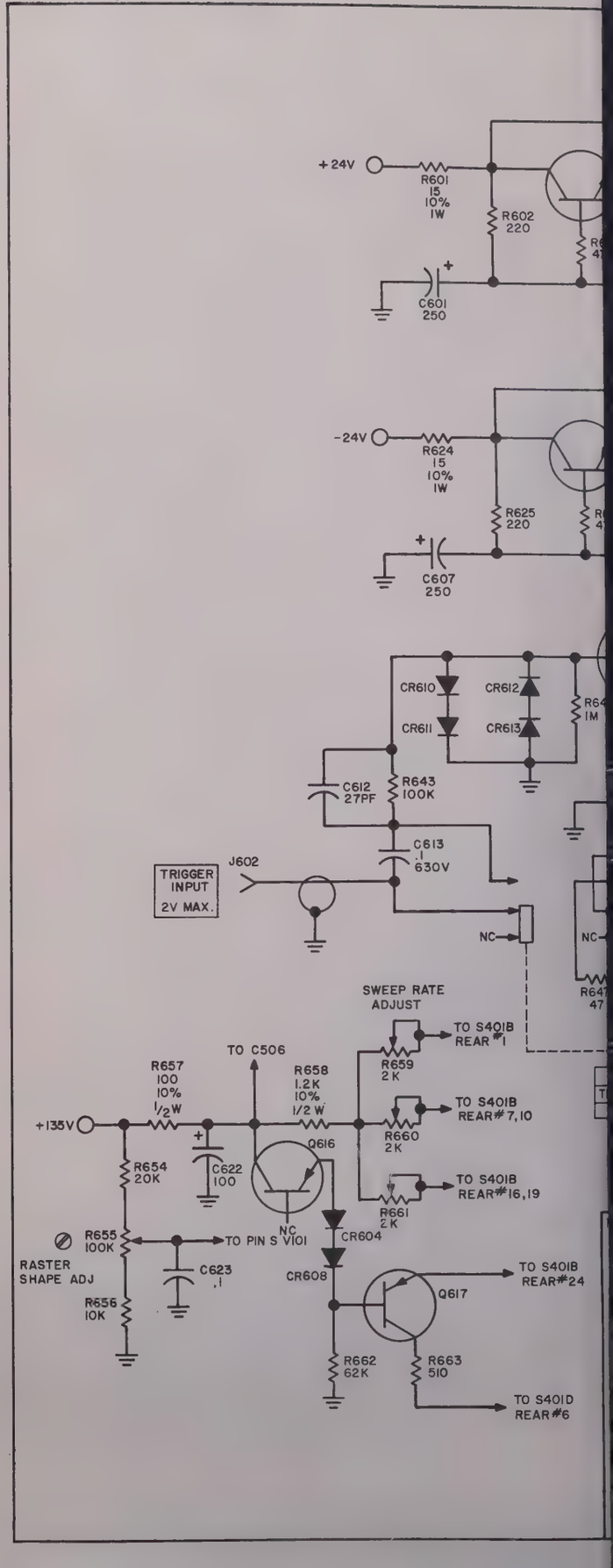
TEST POINT K

.5v/div
20μ sec/div

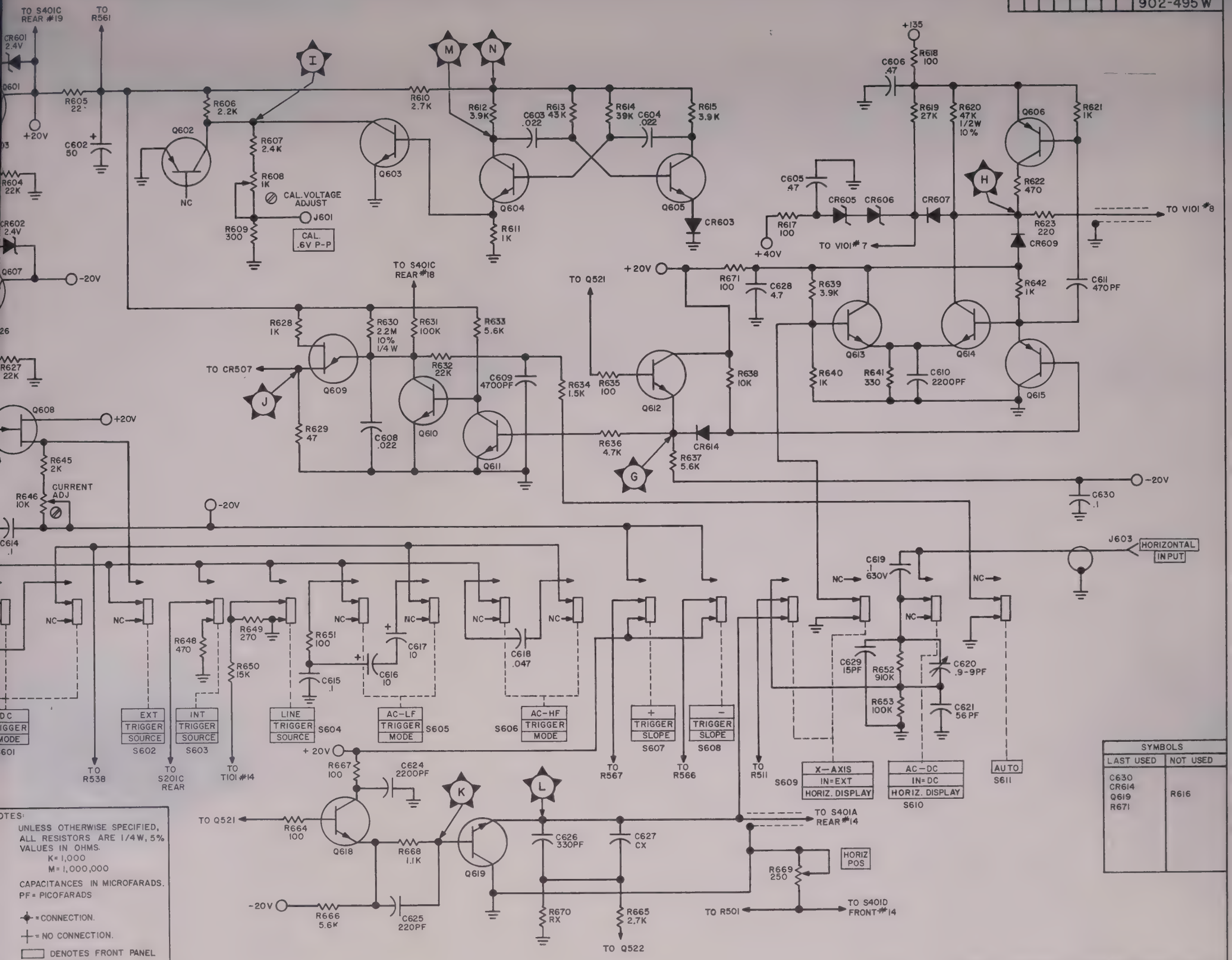


TEST POINT L

.1v/div
20μ sec/div



ALTERATION	DRAWING NUMBER
	902-495 W

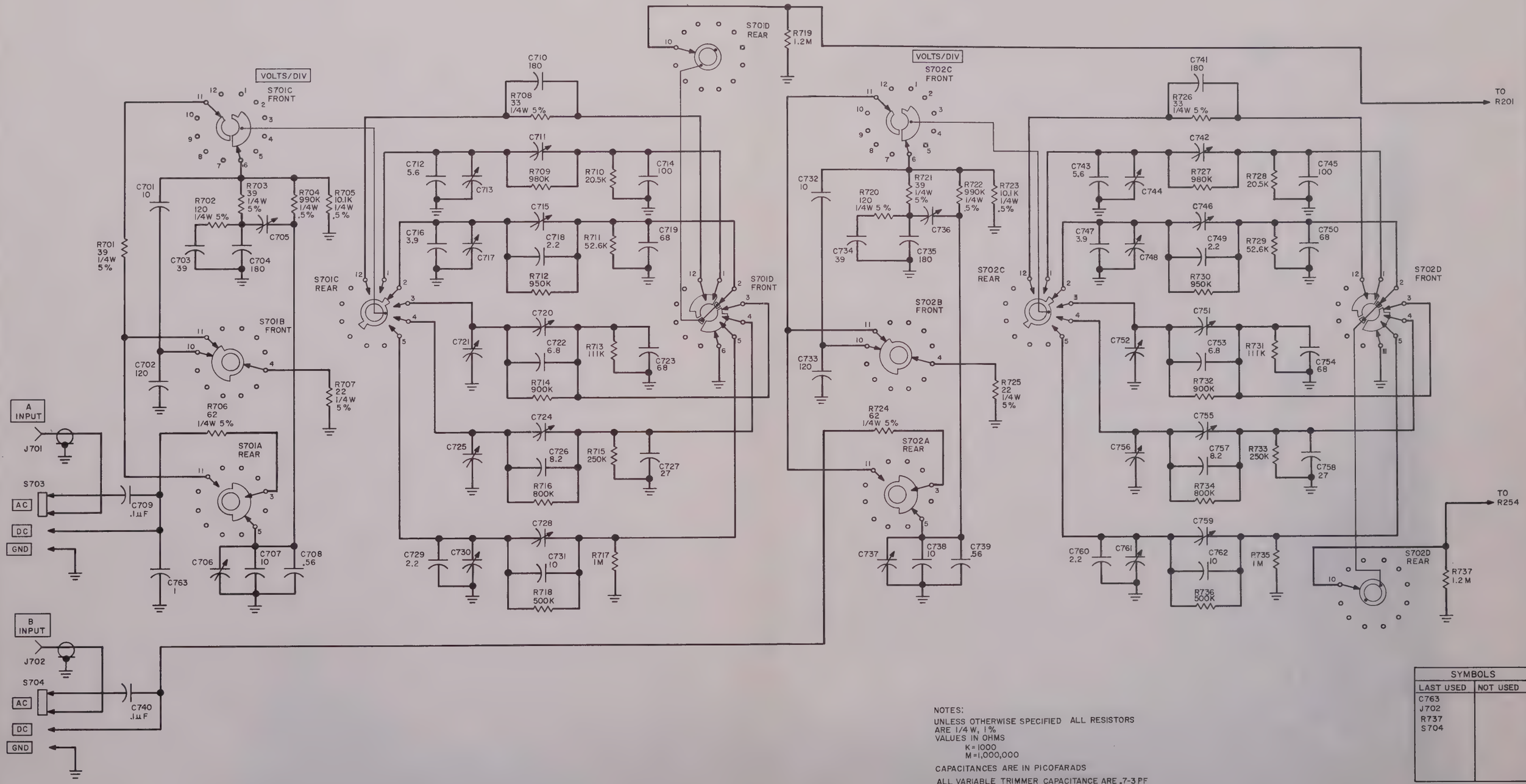


SYMBOLS	
LAST USED	NOT USED
C630 CR614 Q619 R671	R616

NOTES:
UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/4W, 5% VALUES IN OHMS.
K = 1,000
M = 1,000,000
CAPACITANCES IN MICROFARADS.
PF = PICOFARADS
⊕ = CONNECTION.
+ = NO CONNECTION.
▭ DENOTES FRONT PANEL MARKING.
⊘ INTERNAL SCREWDRIVER ADJUST.
RX = CALIBRATION RESISTOR VALUE DETERMINED IN PRODUCTION.

FIG. 33 — SCHEMATIC WIRING DIAGRAM MODEL 5002 HORIZONTAL BOARD B Sheet 6 of 8

ALT.	DRAWING NUMBER
	902-495W

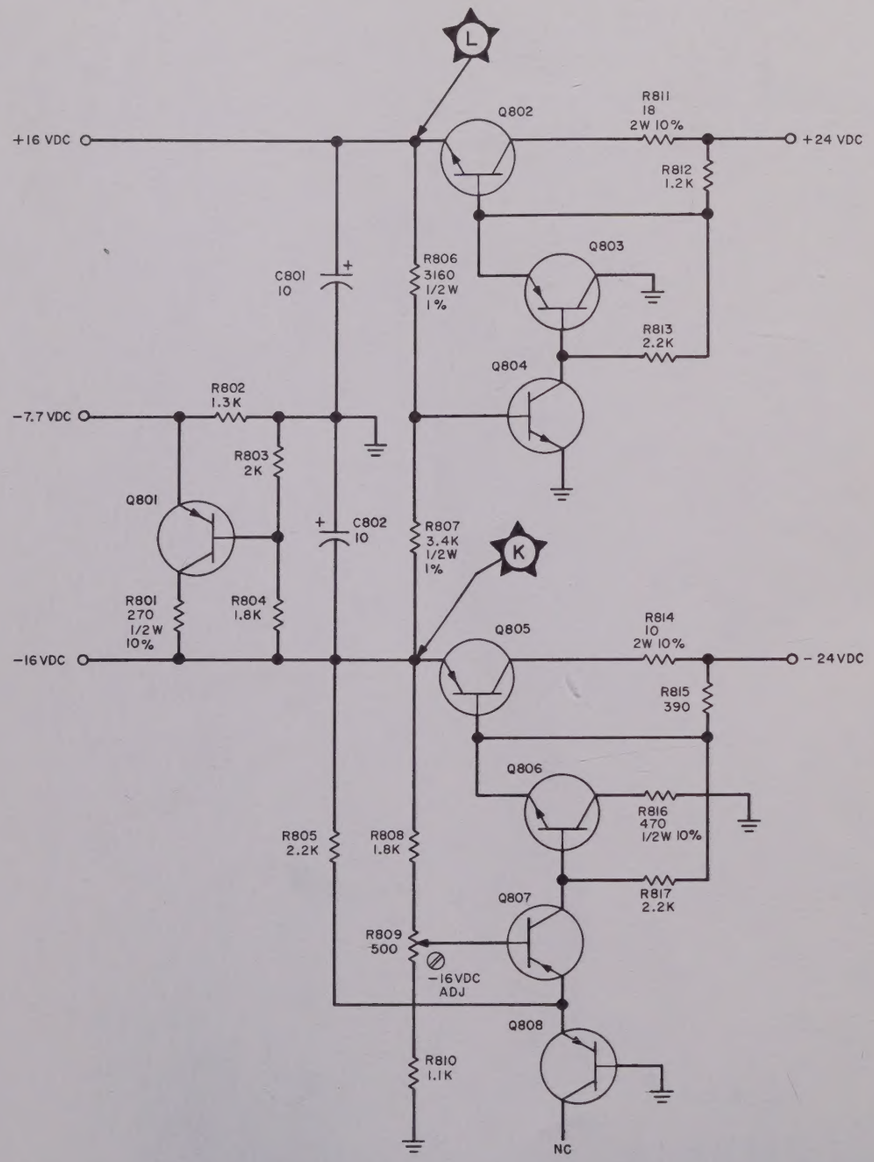


SYMBOLS	
LAST USED	NOT USED
C763	
J702	
R737	
S704	

NOTES:
UNLESS OTHERWISE SPECIFIED ALL RESISTORS ARE 1/4 W, 1%
VALUES IN OHMS
K = 1000
M = 1,000,000
CAPACITANCES ARE IN PICOFARADS
ALL VARIABLE TRIMMER CAPACITANCE ARE .7-3 PF
CONNECTION
NO CONNECTION
DENOTES FRONT PANEL MARKING.

FIG. 34 — SCHEMATIC WIRING DIAGRAM MODEL 5002
VOLTS/DIVISION SWITCH A-B Sheet 7 of 8

ALT	DRAWING NUMBER
	902-495W



NOTES:

UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/4 W, 5%
VALUES IN OHMS
K=1000
CAPACITANCES ARE IN MICROFARADS

CONNECTION

NO CONNECTION

INTERNAL SCREWDRIVER ADJUST

SYMBOLS	
LAST USED	NOT USED
C802	
Q808	
R817	

FIG. 35 — SCHEMATIC WIRING DIAGRAM MODEL 5002
POWER SUPPLY, REGULATED Sheet 8 of 8

LOS ANGELES INSTRUMENTATION AND
COMMUNICATION EQUIPMENT SERVICE
223 WEST [illegible] AVE.
INGLEWOOD, CA 90301